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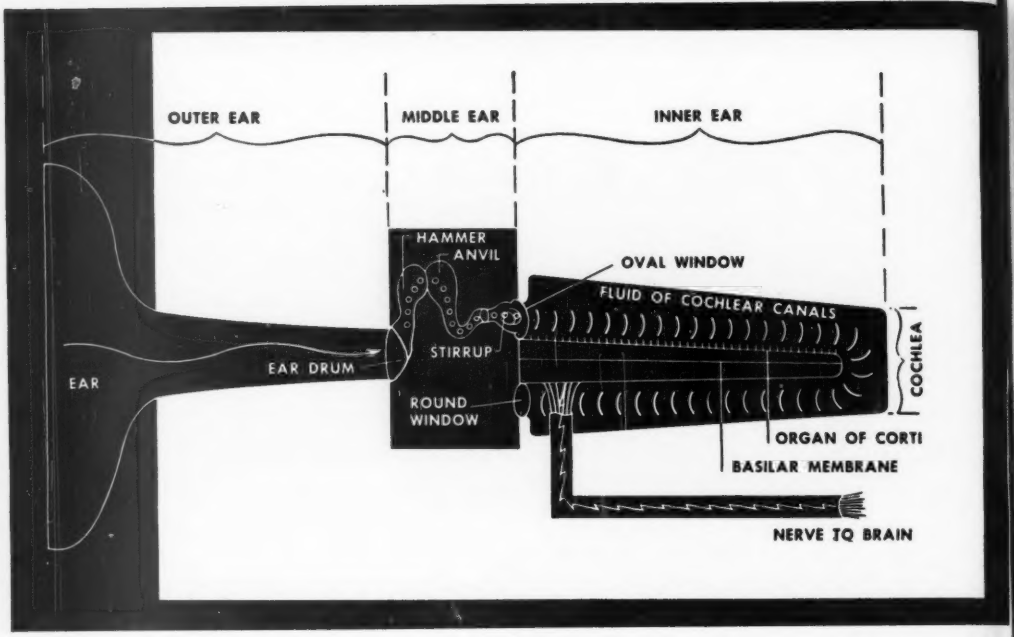

A simple explanation of how we hear NOISE

Today's growing concern about industrial noise has turned the spotlight on the human ear, and an understanding of this wonderful and intricate mechanism is becoming a must for many industrial hygienists. Although much has been published on the ear, we hope this simplified explanation will fill some gaps.

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This hearing process is charted in line symbols on the simplified schematic drawing above. The wavy line [~~~] in the outer ear represents sound waves entering the auditory canal. As these waves reach the end of the canal, they strike the ear drum, causing it to vibrate. These vibrations [ooooo] are picked up by the connecting hammer, anvil, and stirrup bones in the middle ear, and the message is transmitted to the oval window.

The pulsating action of the oval window, caused by the transmitted vibrations, moves the fluid [))))))] in the cochlear canal of the inner ear. The varying pressure from the fluid displacement is accommodated by a flexible round window in the cochlea.

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The Toxicity of the Products Formed by the Thermal Decomposition of Certain Organic Substances

J. F. TREON, J. W. CAPPEL, F. P. CLEVELAND, E. E. LARSON
R. W. ATCHLEY and R. T. DENHAM
The Kettering Laboratory, Department of Preventive Medicine and Industrial Health, College of Medicine, University of Cincinnati

BOTH THE MILITARY services and industry have become increasingly cognizant of the need for toxicological information concerning the products formed from organic substances on contact with metals at elevated temperatures. Accordingly, the immediate toxicity of products resulting from the thermal decomposition of several lubricants, hydraulic fluids, and plastics have been investigated.

In these experiments, the products of thermal decomposition have been more toxic than the vapors or mists of the undecomposed material. Most of the work reported herein has been initiated and sponsored by the Wright Air Development Center, Aero Medical Laboratory, but certain parts of it were sponsored by Monsanto Chemical Company.

It may be of some interest to show that the toxicity of the products arising from the thermal decomposition of a formulated synthetic lubricant which meets the military specifications of MIL-L-7808 is largely that resulting from the breakdown of its principal ingredient, di-2-ethylhexyl sebacate (Fig. 1), and that the presence of a small amount of mixed tricresyl phosphates, the structure of one of which is shown, contributed little or nothing to the toxicity. Of the 10 isomers, the one shown is not present to a large extent, since the tricresyl phosphate was derived from cresols containing less than 3% of the ortho isomer. From a statistical consideration assuming equal rates of phosphorylation, the di-para, monometa and the di-meta, mono-para isomers were present in the largest quantity. Furthermore, the toxicity of the products resulting from the thermal decomposition of this formulation is probably somewhat less than twice that of those formed by the thermal decomposition of a paraffinic hydrocarbon lubricating oil.

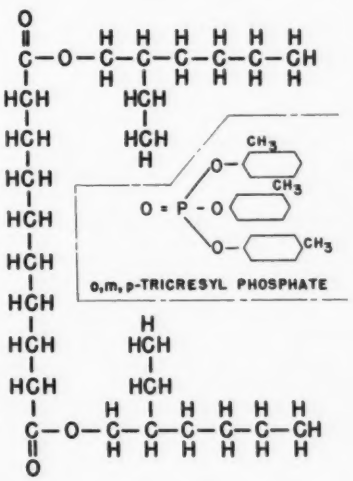

Fig. 1.
Formula for di-2-ethylhexyl sebacate and o, m, p-tricresyl phosphate.

Presented at the Fifteenth Annual Meeting of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, Chicago, April 29, 1954.

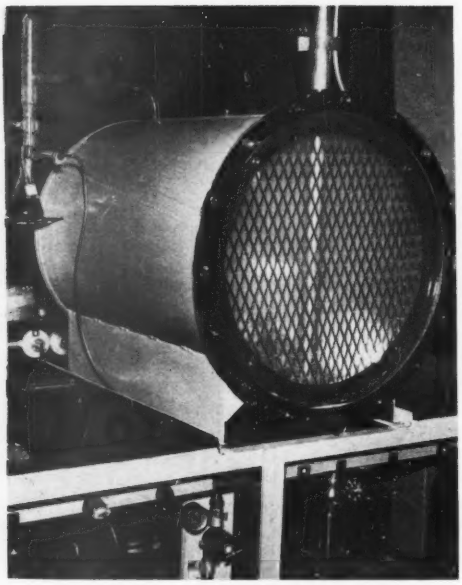

Fig. 2.
Aspirator and 223-liter chamber.

Methods

MISTS were generated by aspiration of the liquids at room temperature, as shown at the left in Fig. 2, by passing compressed air over an orifice,[1] the lower portion of which was immersed in an Erlenmeyer flask containing the material. The intensity of the fog shown in this chamber is of the order of 1 mg per liter (Fig. 2).

The formation of a fog resulting from decomposition of the lubricant at an elevated temperature was accomplished by dropping it at a known rate into an Inconel furnace through the upright tube as shown at the right in Fig. 3. This figure also shows a smaller upright tube to the left through which a thermocouple was inserted into the furnace. Further to the left is shown a condenser coil of Stainless Steel, Carpenter 304, which was immersed in a cooling bath.

Fig. 4 shows a rotameter for measuring the flow of air, the furnace, a semi-potentiometer (for measurement of the temperature of the thermocouple), the cooling bath, the chamber and certain equipment for collecting samples of the atmosphere from the chamber. A schematic diagram of the equipment for generation of a fog at an elevated temperature is shown in Fig. 5.

Results (Esters)

MISTS of either the formulation or of its chief component, di-2-ethylhexyl sebacate, generated by aspiration of air through the lubricant at room temperature, were tolerated by all animals[2] subjected to exposure to concentrations of 1.14 and 0.40 mg per liter, respectively, for seven hours per day on 10 days; however, fatalities occurred among rabbits and rats exposed for only seven hours to the fog resulting from heating the higher of these two concentrations of either the formulation or of its principal ingredient to the temperature of 700°F (Table I).

The mortality in the several groups of guinea pigs exposed to the fog[2] formed by contact of di-2-ethylhexyl sebacate with

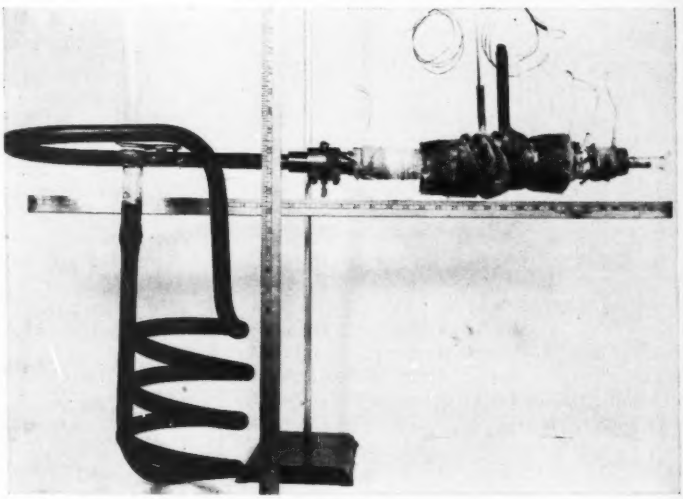

Fig. 3.
Furnace for thermal decomposition and cooling coils.

Inconel at 700°F has been plotted logarithmically in relation to the severity of the exposure in Fig. 6. In this graph, the duration of the exposure in hours has been plotted along the axis of abscissae, and the corresponding rate of delivery of the material in milligrams per minute, along the axis of the ordinates. In all instances, the rate of flow through the furnace was 31.8 liters per minute. The extent to which the circle at a given point is filled indicates the proportion of animals that died under the indicated conditions.

This shows that guinea pigs survived following two hours of exposure, when the sebacate was delivered at the rate of 56 mg per minute (equivalent to 1.76 mg per liter), but that some of them died under otherwise comparable conditions if the rate of delivery was 85 mg per minute (equivalent to 2.67 mg per

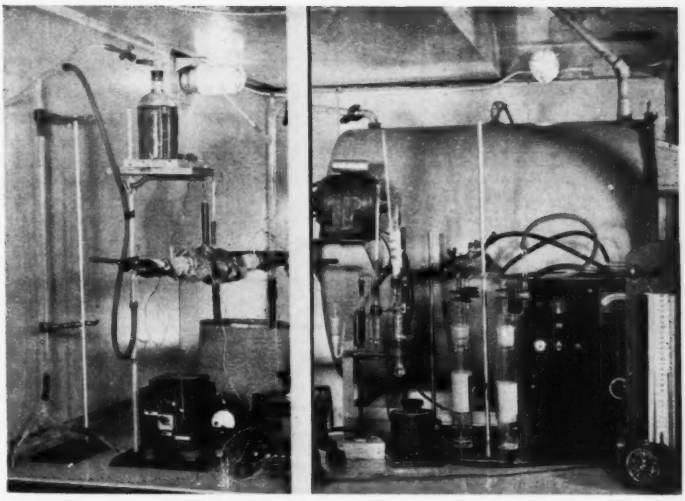

Fig. 4.
Equipment for generation of a fog, chamber and sampling equipment.

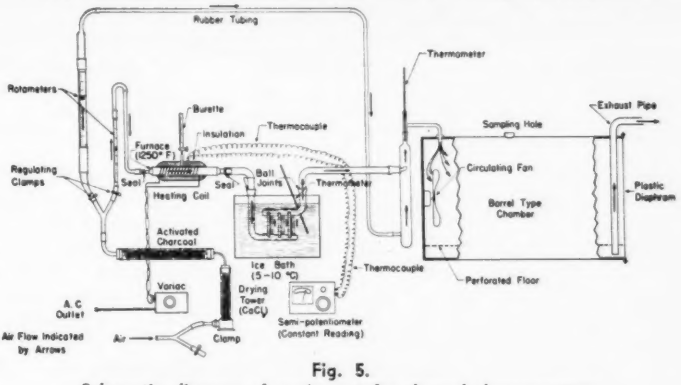

Fig. 5.
Schematic diagram of equipment for thermal decomposition.

TABLE I.
COMPARISON OF THE TOXICITY OF THE MISTS GENERATED BY THE ASPIRATION OF A LUBRICANT AT ROOM TEMPERATURE, AND OF THE FOG FORMED BY DROPPING THE LUBRICANT INTO AN INCONEL TUBE HEATED TO 700°F (371°C.)

Material	Temperature	Concentration of Di-2-Ethylhexyl Sebacate (mg/1)	Duration of Exposure (hours)	Number of Fatalities Per Number of Animals Exposed			
				Cats	Guinea Pigs	Rabbits	Rats
Formulation	Room	1.14[1]	10 x 7	0/1	0/2	0/2	0/2
Di-2-Ethylhexyl Sebacate	Room	0.40[1]	10 x 7	0/1	0/2	0/2	0/4
Formulation	700°F.	0.95[2]	7	—	0/2	2/3	3/4
Di-2-Ethylhexyl Sebacate	700°F.	0.94[2]	7	—	0/2	2/4	3/4

[1]Found by analysis of sample collected from chamber.
[2]Rate of dropping liquid into furnace divided by rate of air-flow (31.8 l per min.) through furnace.

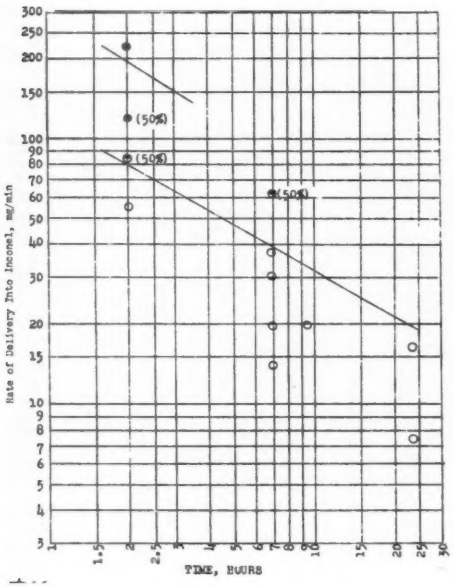

Fig. 6.
Fatalities among guinea pigs following the inhalation of the fog formed by dropping di-2-ethylhexyl sebacate into an Inconel tube maintained at 700°F.

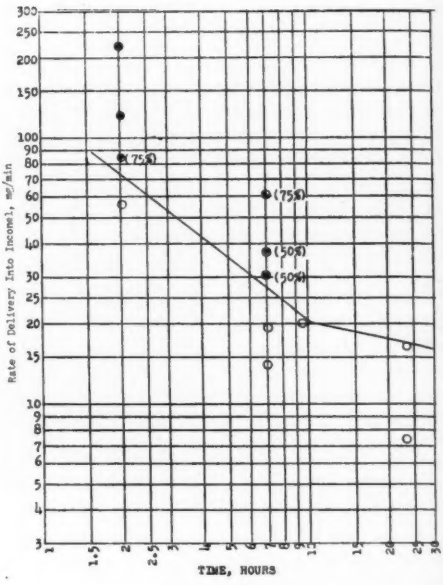

Fig. 7.
Fatalities among rabbits following the inhalation of the fog formed by dropping di-2-ethylhexyl sebacate into an Inconel tube maintained at 700°F.

liter). Likewise, guinea pigs survived following seven hours of exposure when the rate of delivery was 37 mg per minute (equivalent to 1.17 mg per liter) but could not tolerate such a period of exposure when the rate of delivery was 61 mg per minute (equivalent to 1.92 mg per liter). Data obtained on rabbits exposed comparably to the thermal decomposition products of di-2-ethyhexyl sebacate formed at 700°F are shown in Fig. 7, and results of the exposure of rats in Fig. 8. Both rabbits and rats were more susceptible than guinea pigs.

The temperature of decomposition had an effect on the toxicity of the fog formed from di-2-ethylhexyl sebacate. The fog formed at 900°F appears to have been slightly more toxic than that formed at 700°F, while that formed at 600°F differed little in toxicity from that formed at 700°F (Table II). However, when the Inconel with which the material came in contact was maintained at 550°F or 400°F, the fog so created was much less toxic than that formed at 700°F.

In the case of the formulation, greater numbers of comparable experiments were conducted at 700° and 400°F. Under conditions created by the higher temperature, one of 12 guinea pigs died, whereas none of 10 died under those associated with the lower temperature. The fog arising at the higher temperature was lethal to 10 of 17 rabbits, while that formed at the lower temperature resulted in the death of only one of 13 rabbits; 17 of 22 and only one of 20 rats, respectively, died.

The data presented in Table III show that the toxicity of the products of the thermal decomposition of the formulation containing a small amount of tricresyl phosphate was essentially the same as that of the correspondingly decomposed di-2-ethylhexyl sebacate alone. Seven comparable experiments with each of the two substances yielded only minor variations in the mortality among guinea pigs, rabbits and rats. In the case of the guinea pigs, 28% died following exposure to the fog of di-2-ethylhexyl sebacate and 7% died following ex-

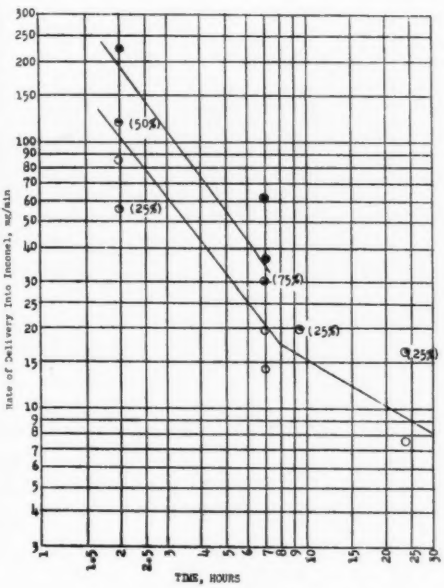

Fig. 8.
Fatalities among rats following the inhalation of the fog formed by dropping di-2-ethylhexyl sebacate into an Inconel tube maintained at 700°F.

posure to the formulation; 44% and 57% of the rabbits, respectively, died and 57% and 54%, respectively, of rats succumbed.

The conclusion that the small amount of mixed tricresyl phosphates contributed little, if any, to the toxicity of the formulation is further substantiated by the difference in the response of guinea pigs to the fogs of either di-2-ethylhexyl sebacate or the formulation, on one hand, and to the fog formed by the thermal decomposition of mixed tricresyl phosphates, on the other. Although the experiments which afford these comparisons were not strictly comparable, in that the temperature at which decomposition occurred was higher (1050°F.) in the case of the phosphates, guinea pigs were more resistant than any other of the animal species to the decomposition products of the ester alone or of the formulation, but they were the most susceptible species to the fog formed from the thermal decomposition of mixed tricresyl phosphates alone. The incidence of mortality among rabbits and rats exposed to the

TABLE II.
THE TOXICITY OF THE FOGS FORMED BY THE THERMAL DECOMPOSITION OF DI-2-ETHYLHEXYL SEBACATE AT VARIOUS ELEVATED TEMPERATURES

Temperature of Inconel (°F.)	Rate of Delivery of the Sebacate (mg/min)	Duration of Exposure (hours)	Number of Animals that Died/Number of Animals Exposed		
			Guinea Pigs	Rabbits	Rats
900	82	2.0	1/2	3/4	2/4
700	85	2.0	1/2	3/4	0/4
700	61	7.0	1/2	3/4	4/4
600	58	7.0	0/2	4/4	3/4
700	37	7.0	0/2	2/4	4/4
550	42	7.0	0/2	0/4	0/4
400	36	7.0	0/2	0/4	0/4
Formulation					
700	20 to 87	7.0	1/12	10/17	17/22
400		7.0	0/10	1/13	1/20

TABLE III.
COMPARISON OF THE FATE OF ANIMALS EXPOSED TO THE FOGS FORMED BY DROPPING DI-2-ETHYLHEXYL SEBACATE OR A FORMULATION CONTAINING IT, INTO AN INCONEL TUBE HEATED TO 700°F (371°C.)

Rate of Air-Flow Through Furnace: 31.8 l/min

Material Added and Rate of Delivery (mg/min)		Duration of Exposure (hours)	Number of Fatalities/ Number of Animals Exposed		
Di-2-Ethylhexyl Sebacate	Formulation		Guinea Pigs	Rabbits	Rats
223		2	2/2	3/3	4/4
	207	2	0/2	2/2	2/2
121		2	1/2	4/4	2/4
	129	2	0/2	3/3	2/2
56		2	0/2	0/4	1/4
	60	2	0/2	0/3	0/4
61		7	1/2	3/4	4/4
	61	7	1/2	3/3	4/4
37		7	0/2	2/4	4/4
	43	7	0/2	3/3	4/4
19.8		7	0/2	0/4	1/4
	19.5	7	0/2	0/3	1/4
7.4		24	0/2	0/4	0/4
	7.4	24	0/2	0/2	0/4
Total	Sebacate		4/14	12/27	16/28
	Formulation		1/14	11/19	13/24
Percentage	Sebacate		28	44	57
	Formulation		7	57	54

decomposition products formed by the three substances did not differ greatly. In the case of the sebacate alone, five of 24 guinea pigs (20.8%) died; in the case of the formulation, only one of 24 (4.2%) died, but in that of the phosphates alone, 10 of 14 guinea pigs (71.4%) died.

An ordinary lubricating paraffinic hydrocarbon was decomposed thermally at 800°F. The responses of guinea pigs to inhalation of the products of this heating of both the paraffinic hydrocarbon and the di-2-ethylhexyl sebacate (700°F.) have been plotted in Fig. 9. Attention is called to the relative position of the lower lines for the two materials separating areas of nonlethal exposure from those associated with the death of some but not all of a group. The line for the paraffinic hydrocarbons relates to concentrations about two to 2.5 times those marked out for the sebacate. The upper lines separate conditions which were lethal for some but not all animals, from those which were uniformly lethal. The latter lines are fairly close together.

Similar data relative to the exposure of rabbits to the paraffinic hydrocarbon or to the ester are presented in Fig. 10. The lines separating tolerable conditions from those associated with the death of some but not all of a group are much closer together than in the case of the guinea pigs, the one for the sebacate being only slightly lower than that for the hydrocarbons.

Fig. 11 represents a comparison of the toxicity of the thermal decomposition products of the paraffin with those of the ester, as indicated by the responses of rats. The time-dosage response to the paraffin was more variable than that to the ester. Under relatively mild conditions of exposure, the more susceptible rat is apt to survive after a more prolonged exposure to the fog formed by the sebacate than to that formed by the hydrocarbon; however, on the other hand, under conditions of greater severity, exposure to the fog of the paraffinic hydrocarbon must be more prolonged than that to the fog of the sebacate, in order to kill all of the animals. Thus, if all of the facts are taken into account, the fog of the sebacate is not much more toxic than that of the paraffinic hydrocarbon.

The increasing steepness of the slopes in passing from guinea pigs to rabbits to rats is noteworthy. When the angle of inclination is 45°, concentration and time are equally effective in the determination of these lines. When the angle is less, then concentration is more important than time, and when the angle is greater, time is the more important factor.

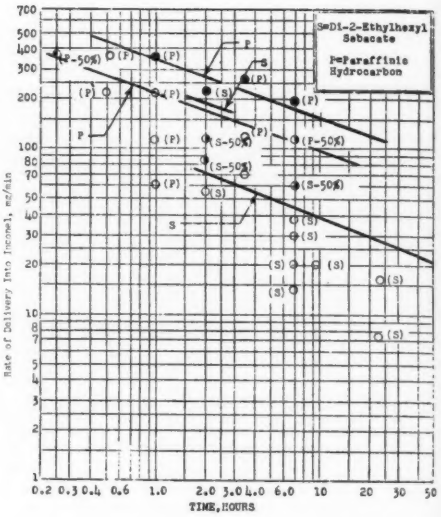

Fig. 9.

Fatalities among guinea pigs following the inhalation of the fog formed by dropping a paraffinic hydrocarbon into an Inconel tube heated to 800°F., or di-2-ethylhexyl sebacate into the tube heated to 700°F.

These fogs produced pneumonitis, and degenerative changes of the brain, liver and kidneys. In the case of the esters and the hydrocarbon, aldehydes, carbonyls, carbon monoxide and undecomposed particulate matter were found in the atmosphere of the chamber. In the case of the tricresyl phosphate, free cresols, undecomposed tricresyl phosphate and carbon monoxide were found.

Results (Halogenated Hydrocarbons)

A SYNDROME similar to that of "metal fume fever" has been reported among men engaged in machining Teflon. This symptom complex has been termed "plastic fume fever."[3,4,5] In view of the dissimilarity in the structure of Teflon and zinc, the extent of the actual difference in their toxic effects is a matter of interest. Is Teflon, when heated, capable of producing the same effects as zinc fume, or does the former induce a more drastic effect and by a different type of action? Graded weights of Teflon-coated copper wire wrapped with an impregnated glass cloth were introduced into an Inconel furnace in which the tem-

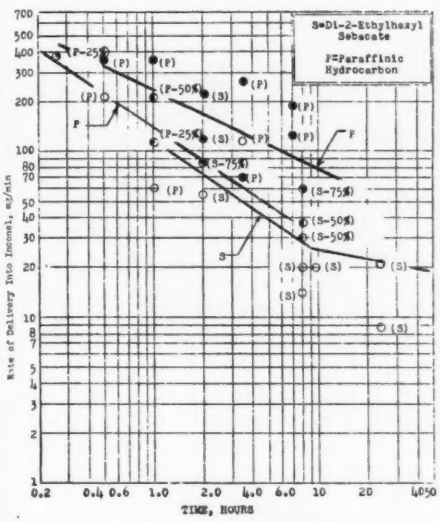

Fig. 10.
Fatalities among rabbits following the inhalation of the fog formed by dropping a paraffinic hydrocarbon into an Inconel tube heated to 800°F., or di-2-ethylhexyl sebacate into the tube heated to 700°F.

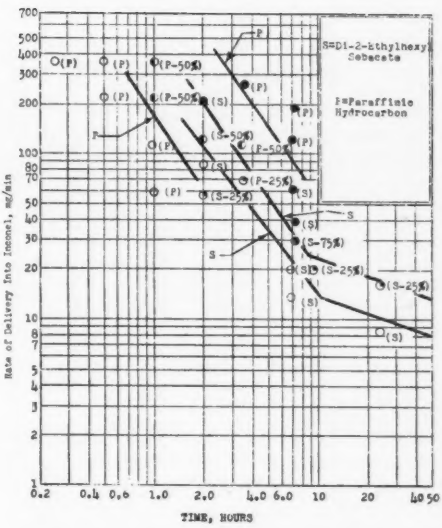

Fig. 11.
Fatalities among rats following the inhalation of the fog formed by dropping a paraffinic hydrocarbon into an Inconel tube heated to 800°F., or di-2-ethylhexyl sebacate into the tube heated to 700°F.

perature was raised rapidly.[6] At temperatures above 400°C. (752°F.) the Teflon appeared to burn rapidly and completely; however, the walls of the furnace were rapidly elevated to a temperature of approximately 800°C. (1472°F.) When animals (Table IV) were exposed for 30 minutes to a progressively decreasing concentration of the fumes formed in the presence of air, the mortality among them varied generally with the amount of Teflon consumed. Cats and dogs, which appeared to be the most resistant of the species of animals employed, died when 14.8 g or more of Teflon were consumed in a stream of 31.8 liters of air per minute, but survived when 6.4 g of Teflon were consumed. Guinea pigs, which succumbed more quickly than other species, tolerated the fumes arising from 1.5 g of Teflon, but some of them died when 3.7 g of Teflon were decomposed. Mice, rats and rabbits were more susceptible to fumes from smaller quantities, deaths occurring among them when only 0.92 g of Teflon was decomposed.

On the basis of a limited number of experiments, the following may be stated:

The presence of the impregnated cloth and the copper wire did not modify the toxicity of Teflon.

Fumes from Teflon heated to 500°C. (932°F.) appeared to be equally as toxic as those formed at 800°C.

Fumes formed from Teflon at temperatures that did not exceed 375° or 390°C. (707° or 734°F.) were much less toxic than those formed at 500°C.

TABLE IV.
MORTALITY AMONG GROUPS OF ANIMALS EXPOSED TO THE THERMAL DECOMPOSITION PRODUCTS OF TEFLON

Decomposition in the presence of air and Cu wire.
Maximum temperature: 800°C.
Duration of exposure: approximately 0.5 hour.

Teflon Consumed (g)	Number of Animals that Died/Number of Animals Exposed					
	Cats	Dogs	Guinea Pigs	Mice	Rabbits	Rats
61.3	1/1	—	4/4	5/5	4/4	6/6
30.0	1/1	—	4/4	5/5	4/4	6/6
15.0	—	—	—	4/5	4/4	6/6
14.8	1/1	1/1	4/4	4/5	1/4	—
6.44	0/1	0/1	4/4	0/5	1/4	6/6
3.72	—	—	3/4	0/5	1/4	5/6
1.51	—	—	0/4	2/5	1/4	6/6
0.92	—	—	0/4	2/5	2/4	3/6

TABLE V.
MORTALITY AMONG GROUPS OF ANIMALS EXPOSED TO THE THERMAL DECOMPOSITION PRODUCTS OF KEL-F

Decomposition in presence of air.
Maximum temperature: 800°C.
Duration of exposure: approximately 0.5 hour.

Kel-F Consumed (g)	Number of Animals that Died/Number of Animals Exposed				
	Cats	Guinea Pigs	Mice	Rabbits	Rats
7.60	1/1	4/4	5/5	4/4	6/6
3.75	—	4/4	0/5	3/4	6/6
1.52	0/1	1/4	2/5	0/4	6/6
0.92	0/1	1/4	1/5	0/4	5/6
0.50	—	0/4	0/5	0/4	0/6

No deaths occurred among animals (five hours of exposure) exposed to fumes of Teflon heated to 300°C.

The fumes formed at 800°C. from 3.6 g of Teflon-coated wire in the presence of nitrogen were at least as toxic as those produced in the presence of air. However, when smaller quantities (0.92 - 1.5 g) were decomposed, those formed in the presence of air appeared to be the more toxic.

Although Kel-F appears to begin to decompose at a lower temperature than does Teflon, the toxicity (Table V) of the fumes formed from the two plastics is of the same order of severity for rats and mice. Rabbits appear to be a bit more susceptible to those from Teflon, while guinea pigs and cats seemed to be more readily affected by those from Kel-F. When Kel-F alone was decomposed in the presence of air (31.8 liters per minute) and the furnace was eventually raised to 800°C., rabbits and cats tolerated the fumes formed from 1.5 g of Kel-F, but died when 3.8 and 7.6 g of Kel-F, respectively, were consumed. Guinea pigs, mice and rats tolerated the fumes from 0.5 g of Kel-F, but some of them died when 0.92 g of Kel-F was decomposed. No fatalities occurred among animals exposed for two periods of five hours to the fumes of Kel-F heated to 200°C.

Animals that died after exposure to the products formed by the thermal decomposition of either Teflon or Kel-F had acute pulmonary irritation (chemical pneumonitis) and diffuse degeneration of the brain, liver and kidneys. The tissues of survivors were normal except for a high incidence of residual pneumonitis and occasionally degenerative changes in the liver. Fig. 12

Fig. 12.
Lungs of a dog exposed to the products resulting from the thermal decomposition of Teflon.

Fig. 13.
Lungs of a control dog.

shows the lungs of a dog which died 3.5 hours after being exposed for 41 minutes to fumes arising from the thermal decomposition of 14.8 g of Teflon. Except in the case of certain guinea pigs that died within a few minutes, the hemorrhagic condition of these lungs is typical of the gross effects of the exposure of animals to the thermal decomposition products of Teflon. A picture of the lungs of a control dog is shown in Fig. 13.

In the case of Teflon decomposed in the presence of air, the total strong acids, expressed as HF, were of about the same concentration as the total ionizable fluorides, but when Teflon was decomposed in the

presence of nitrogen the total quantity of ionizable fluorides was several hundredfold greater. Much finely divided particulate matter was present. Bands suggestive of perfluoroisobutene[7] and oxygen difluoride were found in the infrared spectra of the decomposition products of Teflon, but they were not sought in the case of Kel-F. Otherwise, Kel-F gave similar decomposition products. We are indebted to DR. WILLIAM E. KEISER, of the Central Research Analytical Section of Minnesota Mining and Manufacturing Company, for an interpretation of the infrared spectograms.

Summary

THE TOXICITY of the products arising from the thermal decomposition of a synthetic lubricant was derived largely from its principal ingredient, di-2-ethylhexyl sebacate, and only slightly or negligibly from the small amount of mixed tricresyl phosphates contained therein. The toxicity of the products resulting from the thermal decomposition of the formulation or of the sebacate is probably less than twice that of the products formed by the thermal decomposition of a paraffinic hydrocarbon lubricating oil. Fogs formed at 550° or 400°F. were much less toxic than those formed at 600°F. The products of thermal decomposition are much more toxic than the undecomposed material.

The products arising from heating 0.9 g of either Teflon or Kel-F above 400°C. (752°F.) resulted in the death of seven of 19, and seven of 20, experimental animals, respectively. When larger quantities of these plastics were subjected to heat, a higher incidence of mortality, in association with extensive pulmonary damage, occurred among animals which were exposed to the products created by the higher temperature. From the aspect of public or industrial safety, it is evident that caution should be exercised to avoid the storage of large quantities of either Teflon or Kel-F in any vulnerable area, especially in an enclosed space, since in the event of fire large quantities of toxic fumes could be liberated. Masks that protect against acid fumes, organic vapors, and finely divided particulate matter should be employed in fighting fires involving either of these materials.

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Study Industry's Nursing Needs

THE AMERICAN JOURNAL OF NURSING COMPANY recently made a grant to the Minnesota League for Nursing for a two-year study to develop new programs in nursing education, designed to prepare nursing students to meet industry's basic nursing needs adequately. The study will be conducted by six collegiate nursing schools in Minnesota with the cooperation of the State Nurses Association, the Department of Health, and the Board of Nurse Examiners.

Air Pollution
—SOME EPIDEMIOLOGIC ASPECTS

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AS A PART of the genesis and growth of civilization there are encountered many conditions, all variously affecting the concomitantly growing population. The conditions generated may have associated with them certain phenomena recognizable in the exposed human population. In some instances it was demonstrated that certain conditions carried specific etiologic agents which produced a specific response in the population. An example in the field of air pollution is the catastrophic accident that occurred in 1950 in Poza Rica. No evidence, however, has been presented thus far which would indicate the existence of a functional or biomathematical relationship between a specific air pollutant or a combination of pollutants and some vital index determined for the population exposed to the pollution. Such a relationship has not been demonstrated even approximately nor for a few values of pollutant concentration. Moreover, no evidence has been found which provides for a mechanism accounting for any possible health effects that specific pollutants of varying concentration and duration of action might exert on a human population.

On occasions such as this it is well to recall that when reference is made to a specific cause being followed by a specific effect it is recognized that actually a disease or a condition is the result of an interaction among the agent and host in the environment and the environment itself, this interaction involving a multiplicity of etiologic factors.

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DR. GAFAFER was associated with the Donora, Detroit-Windsor, and Poza Rica studies; and is presently a consultant to the California state air pollution study.

It should be stated, furthermore, that the sickness and death caused directly and indirectly by explosive outbreaks such as those in the Meuse River valley, Donora, Poza Rica, and Greater London leave no doubt whatsoever that polluted air can kill. Moreover, it would be unwise for public health personnel to ignore the teachings of these outbreaks, while they are seriously engaged in the study of the quantitative aspects of health effects. A dictum of factory epidemiology might be appropriately and fruitfully extended to work in community air pollution. This dictum suggests that all pollutants be considered potentially hazardous until proved otherwise.

As will have been surmised, interest is not restricted here to the temporary but spectacular and dramatic phases of the effects of air pollution, but rather the interest has been broadened to include what might be termed the interepidemic periods. The mere absence of recognizable health effects in the interepidemic periods should present no reason for concluding that the quantitative study of such periods is not of value in the elucidation of the air pollution problem. In fact, it is difficult to conceive of a scientific investigation of the problem that fails to consider not only the spectacular episodes but also the phenomena before and after such episodes. The total air pollution problem is thus recognized and introduced.

There is, therefore, a need for the study of the health effects of air pollution. In any attempt to determine these effects quantitatively it would seem that the approach and methods of epidemiology have much to offer. For evidence that this methodology can prove useful in the quantitative determination of biologic effects it is necessary

only to refer to earlier studies such as those performed in the investigation of endemic dental fluorosis.[1] Since the meaning of the term epidemiology is still shrouded in a mist of ambiguity, it is necessary to indicate what it is intended to mean under the present circumstances. *Epidemiology* may be defined as a discipline dealing with the study and analysis of the various elements that determine the frequency and distribution of a disease or condition, the findings eventually becoming useful in the formulation of recommendations for prevention and control. With this definition in mind, it is proposed to refer to some of its implications, and subsequently to some results derived from a number of situations in which interest was centered on the quantitative effects of air pollution on an exposed human population.

Implications of Epidemiology as Defined

THE VARIOUS elements determining the frequency and distribution of a disease or condition may be designated relevant factors. In applying the epidemiologic method all factors believed relevant should be taken into account. Since all factors cannot be thought of, the question of the possibility of having disregarded relevant factors should be constantly borne in mind, and nowhere in the progress of a study is it more essential than in the interpretation of results. The relevant factors reside, first, in the host or in the individuals comprising the exposed population, second, in the agent or combination of agents causing the disease or condition in the population, and, third, in the biologic (animals and plants), economic, physical and social environments that singly or again, in combination, may influence or bring about a reaction between host and agent. In a quantitative study of the health effects of air pollution some of the major relevant factors, referred to the host, appear to be age, health-status, race, sex, psychologic characteristics and inherent traits; referred to the environment, the factors include those arising from the social, economic and physical conditions. It will be observed that relevant factors are not necessarily unrelated.

The definition refers further to the frequency and distribution of a disease or condition. Associated with the problem of air pollution there is, unfortunately, no known disease entity or specific condition. Thus the investigator is faced with a situation that is diametrically opposed to the one presented in classic epidemiology where the existence of a disease entity is known, suspected or assumed.

With no knowledge existing of a particular disease entity, the study of the health effects of air pollution might begin on a basis sufficiently broad to favor the emergence of a disease entity or syndrome from among the numerous possible effects which the study had planned specifically to search for. On the other hand, the investigator may have some experiences which make him feel that certain diseases or syndromes may be associated with air pollution and hence he will be guided accordingly in the planning of his investigation.

Some Inquiries Into Health Effects

WITH THE USE of data derived from past and current air pollution studies it is proposed to give some results bearing on the health aspects of the problem which will at the same time serve to indicate the present status of the methodology employed in assessing health effects. Reference will be made to the London fog of 1952, and the current Detroit-Windsor and California studies.[2,3,4]

London, 1952

DURING the four days of December 5 through December 8 of 1952, an exceptionally severe, dense fog occurred over Greater London. The excess mortality associated with the fog was observed only locally and only by persons concerned with mortality, such as the registrars of death. The disaster and its size were not recognized until death certificates were examined and analyzed.

With regard to the investigation of the various factors believed related to the episode it was not practicable to examine carefully each death or illness, or to adopt the questionnaire approach such as was used on a sample of families in Donora. Furthermore preliminary inquiries revealed that a meticulous investigation of illness would be unlikely to yield material of much usefulness. So it was decided to base the study of the episode primarily on death certificates.

The week ended December 13 was the week of highest registered mortality. During this week there were registered for Greater London a total of 4,703 deaths as compared with an average of 1,852 for the corresponding weeks of the five preceding years. The requisite data were available for London Administrative County for a comparison of registered deaths during the fog with the deaths registered during the cholera epidemic in 1854 and the influenza epidemic in 1918. If only the week of highest mortality is considered it is found that 2,484 deaths were registered during the fog, 4,290 during the influenza epidemic and 3,413 during the cholera epidemic. When calculated on a rate basis, that is, when the deaths are related to the population, the rate during the fog was about one-half of the rate during the cholera epidemic and seven-tenths of the one during the influenza epidemic.

The age factor seemed to be of importance, almost three times as many adults over 45 years of age dying during the week of December 13 as compared with the preceding week; the corresponding ratio for children under one year of age was approximately two.

An examination of the causes of death registered during the week of December 13 showed that the excess of 1,539 deaths over the preceding week included 81% that could be accounted for by disease of the respiratory and cardiovascular systems, respiratory diseases alone representing almost 60% of the total increase. Bronchitis was recorded as the cause of the greatest number of deaths during this week while during the previous week coronary disease held this position.

With the reference to the striking place assumed by bronchitis as a cause of death it is of interest to refer to some recently published work[5] in which a significant positive correlation was reported between the average sulfur dioxide air pollution in the county boroughs of England and Wales and the bronchitis mortality rates for men 45 years of age and over, for the three years, 1950-52. A later paper commenting on this correlation substituted "consumption of domestic coal per acre" for sulfur dioxide and reported a significant positive correlation between the two variables.[6] While it is generally admitted that correlations of this type are in no sense final so far as the solution of a problem is concerned, they are nevertheless in many instances of great value for the useful suggestions they give in connection with the initiation or continuation of clinical, laboratory or field work.

It is significant that the official report on the fog refers to a lack of any clinical or pathologic characteristics associated with deaths during the fog, thus making it impossible to distinguish those deaths from others that might have occurred in the absence of fog. The report concludes: "Consideration of all the evidence available leads to the conclusion that substances in the polluted fog caused irritation of the bronchi and bronchioles and so accelerated death in those already suffering from diseases of the respiratory and cardiovascular systems. In the present state of knowledge it is impossible to state that any one pollutant was the cause of death."

Detroit-Windsor Study, 1949

THE CURRENTLY conducted study in the Detroit-Windsor area was initiated under the auspices of the International Joint Commission which appointed a technical advisory board to carry out the project. The study originated in complaints from residents on both sides of the international boundary that vessels using the Detroit River were causing a smoke nuisance.

The epidemiologic aspects of the study were early recognized. It was agreed that ill-health and even death could be associated with air pollution. But the question of the effects on health of different degrees of air pollution needed investigation.

To secure appropriate data it was decided to use the methodology of the sickness-survey. Accordingly, households in high and low air pollution areas, are visited periodically by trained enumerators who seek answers to questions on current illnesses. These questions pertain to such factors as time of onset of the illness, whether any of a list of sixteen symptoms were experienced, illness severity, and kind of medical care if there was any.

On the first visit information is also got on the household and on the present health status of the individuals of the household.

Household data have to do with such subjects as housing, number of persons and rooms, sanitary conveniences, method of refrigeration, home accessories, heating equipment and type of fuel; data are also secured on age, sex, color, occupation, and socio-economic status of the members of the household. Information on the present health status of the members of the household is obtained with the use of a modified Cornell Medical Index questionnaire whose total of 195 objective questions was replaced by 78. These questions answered by checking a *yes* or *no*, have primarily to do with items believed related to the health aspects of air pollution. Questions on personal habits, physical status, previous illnesses and complaints are prominent in the list.

From an analysis of the collected health data together with those on the air pollutants it should be possible eventually to make a contribution to the quantitative relationship of air pollution to health.

California Study, 1954

DURING THE PERIOD October 15-20, 1954 there occurred in Los Angeles a period of relatively high smog. On October 23 the Governor of the State of California issued a statement from which were developed the objectives of the air pollution study project. The Governor referred, among other things, first, to his desire to be prepared to work with the State legislature in a sound approach to the control and eventual elimination of smog, second, to a scrutiny of the State's role in the development of new knowledge and in the provision of technical assistance in local areas, and, third, to the need for information which would indicate when smog becomes a "killer."[7]

So far as the Los Angeles smog was concerned the California investigators were well aware of some of its characteristics such as, its effect on visibility; its irritating effect on the eyes, nose and throat; its damage to crops, and its ability to produce numerous nuisance problems. Furthermore these investigators were also aware of the dramatic air pollution episodes that killed people, and recognized the absence of knowledge on the health effects of air pollution associated with the periods separating the dramatic episodes.

The recently published initial report on air pollution in California has a number of references to the subject of health effects of air pollution. Of particular interest are the comparisons of certain characteristics of illness suffered in Los Angeles County during smog and non-smog periods. The experiences generally covered the period, August through November of 1954 in which smog episodes occurred from September 21 to 24, October 15 to 20 and November 24 to 28. Brief reference will be made to some of the comparisons.

A study was done on the incidence of illness and injury among the elderly, a group that might be expected to show the effects of smog early. The weekly illness rates per 100 persons varied from 3.9 to 20.6 with the higher rates generally corresponding to non-smog weeks.

Since respiratory illnesses have been associated with air pollution, data on this group of diseases were examined for persons of all ages. The weekly rates varied from 17.8 to 45.0 illnesses per 1,000 persons with apparently no association with periods of smog.

Hospital admissions were also studied with reference to respiratory and heart diseases. Again there was no recognizable relation to periods of smog.

The relation of industrial absenteeism to air pollution was investigated with the use of over-all absenteeism data for October and November from five establishments employing over 6,500 persons. During the eight weeks approximately 2.4% of the employees were absent daily. During the two smog periods the corresponding percentages were 2.5 and 2.2. Thus it seems that for this experience smog was not an important factor with respect to absence from work.

Finally a more severe criterion was introduced in the study of health effects when data were used on deaths attributed to respiratory diseases and diseases of the heart. As indicated earlier these are causes of death which can be expected to appear prominently in episodes of acute air pollution.

During the three smog periods the average daily number of deaths was 46, 49 and 47, respectively. For three smog-free periods the corresponding numbers were 48, 50 and 49, magnitudes differing very little from those for the smog periods.

Comments and Conclusions

A CONSIDERATION of the epidemiology of the three studies referred to indicates that much is still to be learned with respect to the quantitative aspects of cause and effect. In any investigation that might be undertaken the problem immediately arises of the existence of a disease or syndrome associated with a polluted atmosphere. Furthermore the air pollutants themselves also present basic epidemiologic difficulties. Thus it was experienced in one of the studies that when two areas were selected, one with high and the other with low pollution, the time changes in pollutant concentration were often greater within the areas than between them.

Moreover the preliminary review of health data in the California study and an initial inspection of some of the health data collected in the Detroit-Windsor study suggested generally no health effects on the population from air pollution. This absence of correlation does not necessarily signify that air pollution is not responsible for sickness or for hastening death in periods such as those under study. It may mean that the factors chosen as relevant ones in the performance of the studies were only remotely related to the problem or that the methods of measuring were deficient in some respects. Such negative preliminary results indicate that greater efforts be made in the use of the sickness-survey. Eventually it is believed that this technique will disclose valid quantitative information on whether or not sickness is higher in one of two areas each essentially similar in all respects but different with regard to the presence of air pollutants. Such information, if found to be positively correlated with the pollutants, should lead to the discovery of the offending agent or agents.

In the conduct of sickness-surveys perhaps closer attention should be given to the quantitative aspects of the exposure of the population to the pollutants. It is well-known from past industrial experiences that sickness rates, for example, have been unwittingly diluted by using the total factory population as a base for the rate when this population included a small percentage of persons not subscribing to sickness benefits. Inclusion of such persons in the base used to calculate a rate will serve to reduce the size of the actual rate since the sicknesses of these persons are not in the records and hence are not reported. It would seem that similar dilution effects might occur in air pollution health studies when proper attention is not accorded the length of time the different persons in the population are exposed to the pollutants.

Finally while sickness-surveys are continuing and various kinds of laboratory and clinical work are being initiated, some carefully chosen geographic areas might be used for a long-term study of the possible time changes in the correlation of sickness and mortality with atmospheric conditions. Only with concerted action on all fronts can the requisite knowledge be obtained leading eventually to an economically and socially sound air pollution program of prevention and control.

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PLANS for the 1956 Industrial Health Conference, to be held at the Convention Hall in Philadelphia from April 21-27, 1956, are well under way. Information on space for scientific exhibits may be obtained from ALLAN J. FLEMING, M.D., 11400 Nemours Building, Wilmington, Delaware.

Dust Counting Reliability

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IT IS THE PRACTICE in industrial hygiene to collect a sample of dust from the air, and to count the dust, when suspended in liquid, reporting the results as so many millions of particles per cubic foot of air. Usually the results are reported to two significant digits. The counting is carried out by a standard procedure,[1] and errors are kept to a minimum. It has long been known that a second count of the same sample will yield a new answer which may support the first or depart sharply from it. Consequently, the reported figure implies a far higher degree of reliability than it actually possesses. Considerable tolerance has been afforded this situation because of the known complexities of atmospheric sampling, and the calculated result is always given a broad interpretation.

A number of workers have been interested in the usefulness of an over-all figure representing the dust concentration in air, and worthwhile studies of reproducibility[2] in sampling have resulted. However, others have been interested in an interpretation of a dust count which will remove the doubt created by the counting technique, and place in proper perspective the errors introduced by the sampling procedure, the sampling apparatus, or at other points. Student[3] long ago investigated the basic theory of dust counting, and Moore[4] recently applied statistical procedures to counting waterborne organisms.

It is the purpose of this paper to show that statistical procedures can be applied to the standard dust counting method, that the reliability of the dust count can be quickly calculated, and that new insight as to the usefulness of the dust count can be gained. The information presented applies equally well to counts obtained by the microscope or microprojector, and may also be applied to procedures for counting blood cells, bacteria, etc.

The standard procedure for measuring the concentration of a dust suspension requires that two cells one millimeter in depth be prepared from the parent suspension which has previously been diluted to give approximately 50 to 75 particles per 0.25 square millimeter. Five fields are counted in each cell (at proper magnification, resolution, etc.) to obtain the average number per field. Data developed in a previous project[5] showed that repeated counts of the same dust suspension will produce answers which differ by as much as 88%. It is necessary to use statistical methods to learn the reliability of the calculated concentration.

Theory

THE USUAL approach in treating a sample of 10 observations (10 fields in this case) is to obtain the mean, and then the standard deviation by

$$\sigma = \sqrt{\frac{\Sigma(x-m)^2}{N}}$$

Where m = mean number of particles per field
x = number of particles per field
N = number of fields

The standard error of the mean

$$(1) \quad \sigma_m = \frac{\sigma}{\sqrt{N}}$$

then shows the sampling error of the mean even in a population with somewhat skew distribution. The mean can be said to lie within plus or minus $2\sigma_m$ 95 times in 100, and as σ_m becomes smaller, the mean becomes more reliable. While this is useful information, the loss of time in calculating σ for each dust sample in a large survey discourages interest.

However an easier method is available. In 1907 Student[3] showed that particles distributed by liquid suspension within a haemocytometer were arrayed according to

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a mathematical law known as the Poisson Distribution. The frequency f of each field value x is given by

$$f = \frac{e^{m}\ m^{-x}}{x!}$$

Happily the standard deviation of the Poisson Distribution is

$$\sigma_p = \sqrt{m}$$

and the standard error becomes

$$\sigma_m = \sqrt{\frac{m}{N}}$$

Admittedly from (1) the reliability of the mean will become better as N increases, and P, the relative error of the result, becomes less as more particles are counted.

$$P = \frac{\sigma_m}{m}$$

$$= \frac{1}{\sqrt{mN}}$$

$$(2) \quad P = \frac{1}{\sqrt{\Sigma X}}$$

Fig. 1 shows the value of P in (2) from which may be calculated the reliability of a mean obtained from any total number of particles. As a practical example, the following typical counts obtained by microscope are

Cell 1	Cell 2
68	69
69	56
60	57
49	48
55	59

$\Sigma X = 590$

$m = 59$

$$\sigma_m = \sqrt{\frac{m}{10}} = 2.43$$

If $2\sigma_m$ is used to establish the confidence limits of the mean, then it can be said that the mean lies within plus or minus (2) (2.43) = 4.86 or within the range 54 to 64 (when rounded off) 95 times out of 100.

In using Fig. 1, P is 0.041 for 590 particles

$$\frac{\sigma_m}{m} = .041$$

$$\sigma_m = (.041)(59)$$

$$\sigma_m = 2.42$$

$$2\sigma_m = 4.84$$

which is very close to the calculated value, and will produce the same confidence limits of 54 and 64. Since the reliability of a count decreases rapidly as the total number of particles becomes less, counts of ten fields from very dilute suspensions or counts made on the microprojector where higher magnification produces fewer particles per field than with the microscope make the final result less reliable than the example above.

Significance of Difference

AT TIMES it is necessary to know whether two dust suspensions are similar or dissimilar. Since the count produces its own variation, it will often mask the answer leaving any conclusion open to doubt. Student presented a simple equation for solving such a problem by comparison with the obtained difference.

$$(3) \quad \sigma_{m_1-m_2} = \sqrt{\frac{m_1}{N_1} + \frac{m_2}{N_2}}$$

where $\sigma_{m_1-m_2}$ = standard error of a difference

m_1 = average number of particles per field from N_1 fields

m_2 = average number of particles per field from N_2 fields

For the standard method of dust counting using 10 fields (3) is simplied to

$$(4) \quad \sigma_{m_1-m_2} = \sqrt{\frac{m_1+m_2}{10}}$$

The standard error of a difference is distributed normally and confidence limits are set accordingly. For example, if $m_1 = 30$ for dust suspension A and $m_2 = 25$ for dust suspension B, a difference between A and B is not certain, but only presumed. However

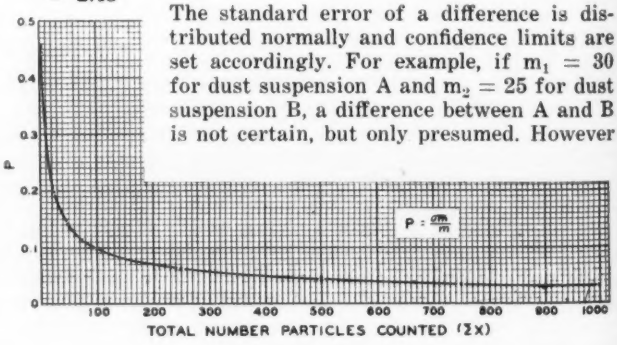

Fig. 1.
Variation of reliability with total number of particles counted.

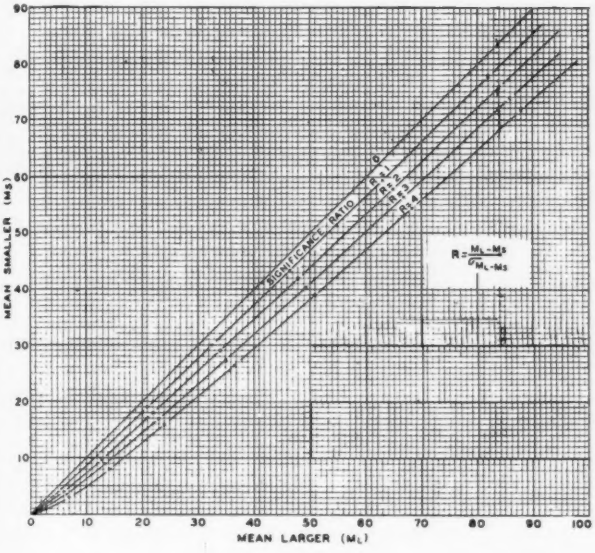

Fig. 2.
Significance ratio for two dust suspensions (each mean obtained from 10 fields).

$$\sigma_{m_1-m_2} = \sqrt{\frac{30+25}{10}}$$
$$= 2.35$$

The significance ratio R, the ratio of m_1-m_2 to $\sigma_{m_1-m_2}$ is then

$$R = \frac{30-25}{2.35}$$
$$= 2.13$$

Reference to a table of areas under the normal curve shows at R = 2.13, A = 96.68. If A and B were in truth the same, then a difference of five or more would have occurred *by chance alone* about three times in 100. Since this possibility is slight, we infer that something more than chance caused the difference and, consequently A must differ from B.

Fig. 2 presents graphically R based on (4) for various mean values so that differences may be explored quickly. It should be noted that the larger mean and smaller mean must be used as shown.

Dust Count Data

IN INVESTIGATING the method of calculation described above, it seemed advisable to study dust counts from a standard suspension whose concentration was known with considerable certainty. A suspension of ground limestone in iso-propyl alcohol was prepared, and fifty cells were counted by microprojector in the standard manner during a period of one week. Fig. 3 presents the distribution of cell means obtained ranging in this case from 18 to 27, and having a mean of 23.2 particles per field for the entire 250 fields. The mean has now been established with considerable certainty, and the standard deviation of the distribution about this mean is

$$\sigma_p = \sqrt{23.2}$$
$$\sigma_p = 4.82$$

In actual usage, our knowledge is confined to counts of two cells, and we wish to obtain the best estimate possible from meager information on distribution. Fig. 4 presents the ratio of calculated σ to 4.82, and also the ratio of σ_p to 4.82 for each cell of the standard suspension. It is seen that in each cell the true value of 4.82 is approached far more closely by the cell σ_p than by the cell σ.

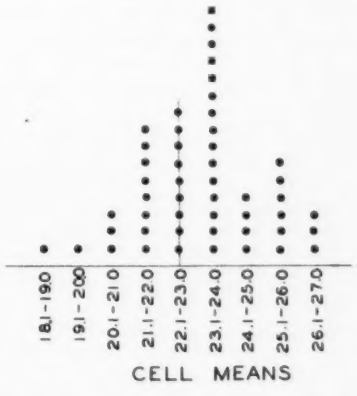

Fig. 3.
Frequency diagram for standard suspension means obtained from 50 cells (5 fields each cell).

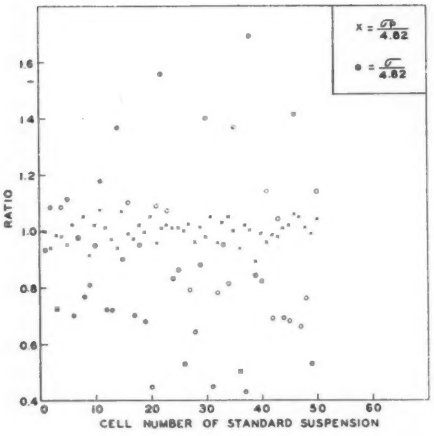

Fig. 4.
Ratio of σ and σ_p for each cell to the known σ_p for standard suspension (σ_p = 4.82 for standard suspension).

The σ_p can be relied upon as consistent while σ is not consistent.

Assigning the confidence limits of the mean as in the example above presumes that the distribution of the sampling mean is normal. It is known that frequently the distribution of sampling means is nearly normal, even though the population sampled is skew.[6] Since the Poisson Distribution is skew in lower values, it must be determined whether the means from samples of 10 are distributed normally.

A review of the means of pairs of cells from the standard suspension was not conclusive as only 25 pairs were available. However, when the mean of each cell was considered (the mean of 5 fields), then data from 50 cells could be analyzed with reasonable confidence in the results. Table I shows how the observed frequency of cell means compares with the theoretical frequency expected from normal distribution. Close to the mean, there is little agreement, but values within one standard deviation or more show close agreement between observed and expected frequency. It is reasoned that since the mean of five fields shows a satisfactory approximation of normal distribution, the mean of 10 fields will show as good or better approximation. The method of calculating reliability described above seems satisfactory.

TABLE I.
DISTRIBUTION OF CELL MEANS IN STANDARD SUSPENSION COMPARED TO NORMAL DISTRIBUTION (AVERAGE 23.2)

Cells Between (Inclusive)	Region of Cells Observed		Percent of Total Cells	
	$-\sigma$	$+\sigma$	Normal	Observed
22.0-24.0	.622	.415	39.4	54.0
21.5-24.5	.881	.673	56.1	68.0
21.0-25.0	1.14	.935	69.8	72.0
20.5-25.5	1.40	1.19	80.3	78.0
20.0-26.0	1.65	1.45	87.8	90.0
19.34-27.06	2.00	2.00	95.5	98.0

Sources of Error

THE OBJECTIVE of dust sampling is to determine the concentration of dust in the air. Many errors are possible between the selection of sampling site and calculation of the final result, and it is not our objective to examine these in detail. However, some knowledge of the dust count operation as described earlier, and also as noted from laboratory experience, will provide better appreciation of the sources of error, which will be discussed in part at this time.

Sampling Apparatus

THE GREENBURG-SMITH impinger is standard in industrial hygiene, and has been tested in a number of excellent studies, one being the Bureau of Mines[2] study of 1949. In the Bureau of Mines study, impingers were set side by side in two's and three's under conditions presumed equal, and the concentrations measured by each were presented as ratios. On this basis certain statistics were calculated, and conclusions on reproducibility reached. In Study No. 3 and No. 4, two impingers were set side by side (at distances roughly between 1 inch and 10 feet) within a mine, and simultaneous samples collected. The data tabulated in this study are examined in the present paper only as source material for further inquiry. The data from each pair have been corrected for slight differences in air volume, and the significance of the difference determined for each pair by R. Fig. 5 presents R and the Concentration Ratio for each pair. Many pairs are seen to differ significantly suggesting a difference in dust exposure as suspected by the Bureau of Mines. However, we are in reality still comparing liquid dust suspensions rather than dust concentrations in the air as the sampling device

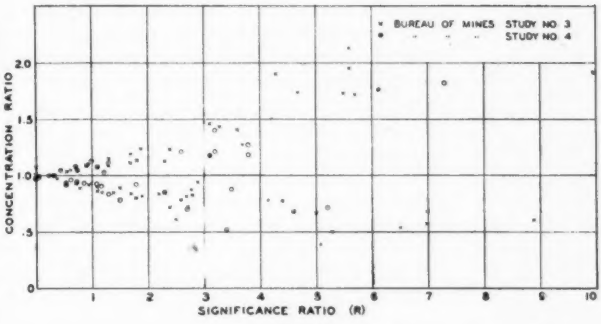

Fig. 5.
Comparison of concentration ratio and significance ratio for pairs of impinger samples.

has not yet been considered. For purposes of this investigation, R = 3 is used as the line of discrimination between those suspensions proven to differ and those suspensions not proven to differ. Those with R<3 will be presumed to be the same since not shown to be different.

Reference to Fig. 5 shows that any value of the Concentration Ratio used as a basis for discrimination will include pairs known to differ, and exclude pairs presumed to be the same. It will not serve as a useful guide in selecting or rejecting pairs.

If we consider this entire sampling project, two questions present themselves: (1) Are the dust concentrations at the intake of each impinger equal? (2) Are the collection characteristics of each impinger equal?

The variation inherent in the dust count prevents an immediate answer from concentration data. However, if we review the suspension data for study No. 3 and reject those pairs whose suspensions differ, we have 45 pairs with equal suspensions. The air volumes sampled and liquid volumes are equal. Therefore, equal suspensions could have occurred in two possible ways: (1) The concentrations are equal and the collection characteristics are equal, or (2) The concentrations are different and the collection characteristics are different, but the low efficiency impinger is always in the higher dust concentration.

The second possibility is not very likely since it is such an exacting condition. However, we can examine the collection characteristics directly. Presumably the impingers were placed without favoring either, and both have had equal chance of exposure to the higher concentration. In 66 tests we can assume that each has had similar exposure, and that any differences in concentration at the intakes have cancelled each other. Therefore, any differences which appear are the result of differences in the collection characteristics of the two impingers.

Calculations from the corrected count data are shown in Table II. Since these tests were run as paired samples, the mean and standard error of the differences between pairs have been obtained.

TABLE II.
BUREAU OF MINES STUDY NO. 3—STATISTICAL VALUES FROM CORRECTED COUNTS PER FIELD (66 TESTS)

Mean Number per Field	
Impinger A	30.85
Impinger B	29.84
Mean Difference Between Pairs, m_D	6.108
Std. Dev. of Differences Between Pairs, σ_D	6.01

Then $\sigma m_D = \frac{\sigma D}{\sqrt{N}}$ where σm_D = the standard error of a difference

$= \frac{6.01}{\sqrt{66}}$

$\sigma m_D = .739$

$R = \frac{A - B}{\sigma m_D}$

$= \frac{30.85 - 29.84}{.739}$

$R = 1.37$

Since the significance ratio R is not excessive, the difference in the mean number per field of A and B may well be a chance difference. No difference in the collection characteristics has been established by these tests although some doubt does exist. However, if a difference does exist, it must be small, since the mean of A and the mean of B differ by only 1.01. As no difference has been proven, it is likely that the 45 equal pairs were produced by the first condition. Tentatively, we say that in 45 cases the dust concentrations at both impingers were the same or nearly so, and in 21 cases the concentrations were different.

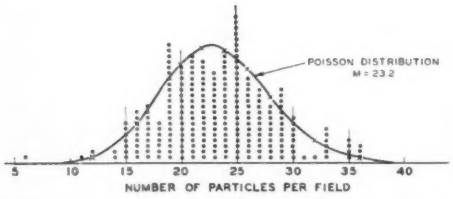

Fig. 6.
Standard suspension distribution of fields from 50 cells (mean = 23.2 per field).

Uniformity of Suspension

LITTLE ATTENTION is directed to the mixing process in the parent suspension, and some doubt has arisen that a proper sample is placed in the dust cell. In our laboratory it has been assumed that a vigorous shaking and immediate filling of the cell through a fast-flowing pipette (tip broken off) was sufficient. Data from the standard suspension were again marshalled to study any variation which might exist. Since it is known that within a cell the particles follow a Poisson Distribution, it was reasoned that if all 250 fields of the standard suspension followed the distribution expected from one cell, then all 50 cells must have been uniform or nearly so. Fig. 6 shows the distribution of all 250 fields from the standard suspension, and also the Poisson Distribution for m = 23.2. The fit by appearance is reasonable, but the Chi Square test for goodness of fit is

$$P = 0.62$$

which shows a very satisfactory relation between theory and observation.

Calculation of the standard deviation for the entire 250 fields shows $\sigma = 5.12$. The standard deviation for the Poisson Distribution for m = 23.2 was found to be $\sigma_p = 4.82$ which is 94% of the calculated value. This also suggests that the field distribution from 50 cells is very similar to the field distribution expected from one cell. Indications are, therefore, that vigorous shaking and immediate removal from the parent suspension will give uniform samples.

Proper Dilution

IT IS CONFUSING to count particles accurately when the number per square in the Whipple Disk is too high. The following laboratory experience, while far from a complete study, shows the need for limiting the concentration. The 25 squares of the Whipple Disk cover 0.25 sq. mm. and the microprojector has a field which covers 0.05 sq. mm. so that the ratio of total counts of the same suspension should be 5 to 1 on the average. However, seven cells, having an average concentration of 135 particles per 0.25 sq. mm., counted on both the microscope and microprojector produced ratios of:

2.94	4.60	3.66	Average 3.77
3.92	3.49		
4.34	3.45		

Additional cells were prepared from new suspensions in which cells for microscope counting contained suspensions diluted four times above the parent suspension counted by microprojector. The microscope counts now averaged 45 particles per field and were definitely less confusing to the eye. After making the correction for the 4 fold dilution, the ratios of microscope to microprojector counts were:

4.09	5.39	Average 4.90
5.48	5.20	
4.33		

This is much improved over the first average ratio of 3.77, and supports the concentration of 50-75 particles per 0.25 sq. mm. recommended in the standard method.

Acceptance or Rejection of Cell Counts

ANOTHER POSSIBLE source of error is the interpretation which is given to the two cells counted for each dust sample. There is at present no systematic way to determine whether the cell total determined by count is "good" or "bad," and each worker has his own feeling in the matter. It is only human nature to feel successful when two cells of the same sample show cell totals which are nearly equal unmindful that this is only a chance result rather than dependent on ability. Other counts equally good may produce a pair of cells whose totals lie at some distance from each other. When this happens and the dispersion is great enough, a third cell is counted to allay a feeling of uneasiness. There is no agreement on when a third cell is to be counted or whether it should be included in the calculation.

Recently work published by Youden[7] on the statistics of measurements in pairs and

triads offers a solution to this problem. This information can be applied to the dust count to minimize the chances of including blunders or excluding useful values. First, however, there must be some knowledge of the expected average difference between two cells from the same dust suspension. An analysis of 1344 dust counts (two cells each) was made to determine the average expected difference between cells under several conditions. This information, about equally divided between the microscope and microprojector, was the result of many counts by each of five persons. In every case, the standard light field method was followed in all details with the exception of proper dilution. It was found here as with many other laboratories[8] that expediency allowed counting with concentrations often far higher than the recommended 50 to 75 particles per 0.25 sq. mm. Concentrations less than this, of course, are often caused by short sampling time.

In Table III it is shown that the average difference for all microscope cell pairs, 31.69, is about the same as for those pairs having the recommended concentration, 27.53. The microprojector results for the same comparison are sharply different, being 17.52 for all data and 6.41 for the pairs having the recommended concentration. It is very encouraging that the same number of particles counted by either microscope or microprojector will produce nearly the same average difference, 27.53 and 25.10. This difference is not statistically significant, and the average is 26.32. This bears out the earlier statement that reliability depends on total number of particles counted.

TABLE III.
AVERAGE DIFFERENCE OF CELL TOTALS IN 1344 DUST SAMPLES COUNTED BY STANDARD METHOD

Instrument	Number of Pairs of Cells	Dilution Range Avg. no. part/fld.* High	Low	Difference in Cell Totals (5 fields each cell) High	Low	Avg.
Microscope	678	546	3	325	0	31.69
	124	75	50	118	0	27.53
Microprojector	666	362	9	534	0	17.52
	24	15†	10†	26	0	6.41
	77	75	50	132	0	25.10

*A field is 0.25 sq. mm. for microscope and 0.05 sq. mm. for microprojector

†Since the microprojector field is only 20% of the microscope field, the recommended concentration will show only 10-15 particles per field.

Youden[7] points out that two measures will differ by less than 2.45 times the average expected difference 95 times out of 100. It is recommended that the standard method be followed in industrial hygiene procedures so that results will be comparable among all workers as originally intended. The confidence level of 95 out of 100 chances is also in accord with current statistical practice. Therefore, the maximum difference to be accepted from two cells having cell totals ranging from 250 to 375 is (2.45 x 26.32) = 64.48.

If the difference is 65 or greater, one cell is open to suspicion, but there is no inkling as to which cell. Further, we know that 5% of the time cell counts can be correct and still have a difference of more than 65. In this situation a third cell should be counted. If we count a third cell, there is no justification in keeping the third cell and the cell closest to it. The rejected cell is not necessarily in error, and a sample of three measurements is better than a sample of two. Study of triads shows that 95 times out of 100 the overall range in a triad will not exceed 2.96 times the average difference for a pair. Consequently, if all three cells differ by no more than (2.96 x 26.32) = 77.91, all three cells may be accepted and should be averaged to obtain the dust count. However, if the difference is 78 or greater, it may be presumed that something is wrong with one cell and rather than include a blunder, it is better to average the third cell and the one closest to it, and reject the remaining cell.

In actual practice, it was found that 13 in 201 samples at an average cell total between 250 and 375 particles should have been checked for acceptability by counting a third cell, but only 1 of the 13 was checked. In microscope data for all concentrations, 57 of 678 samples should have been checked, but a third cell was counted in only six cases. In microprojector data for all concentrations, 48 of 666 samples should have been checked, but a third cell was counted in only three cases. The test for the acceptance of a triad showed that one of the nine checked cases above had an unacceptable cell, probably a blunder.

There is not enough data in the 50 counts of the standard suspension to judge the usefulness of Youden's method directly. How-

ever, its application to dust counting was reviewed indirectly by studying the 1344 dust counts on record. Youden states that 5% of the cases will exceed by chance alone the difference limit of 2.45 x 31.69 for microscope counts. In the 678 cases recorded, 8.86% were found to equal or exceed the difference of 78. For the microprojector, the difference of 43 was equalled or exceeded 6.61% of the time in the 666 cases recorded. It is expected that a certain number of blunders will have occurred which will also fall beyond the difference limit in both cases. Therefore, it is not surprising that both situations exceed 5% by a little. If total counts having a range of 250 to 375 particles per cell are considered, 5.97% of the 201 cases are found to equal or exceed the difference limit of 65. This seems reasonable since it is known that blunders are less likely to occur in the lower concentrations. Indications are that Youden's method is quite satisfactory when applied to dust counting.

Customary Levels of Reliability

THE REPORTED dust concentration is calculated by applying a series of constants (dilution, cubic feet of air sampled, etc.) to the mean number of particles per field obtained from 10 fields. Therefore, any unreliability in the mean number per field is also embodied in the airborne dust concentration in the same percentage. Some appreciation of the usual levels of error associated with the reported concentrations can be found in the 1344 recorded dust counts. Fig. 7 shows the frequency of dust counts (two cells) having total numbers of particles of the ranges shown. From this cross section of samples and from Fig. 1, the most frequently reported count for the microscope carries a possible error of 9% to 14%, and for the microprojector the possible error is 12% to 14%. From Fig. 7 it can be seen that either the recommended concentration is not considered important or the difficulty in estimating proper dilution without several false guesses first encourages laxity. Fig. 8 shows the spread of error possible in reporting a concentration of 1 million particles per cubic foot based on various total numbers of particles counted. The percent error decreases as more particles are counted. However, if

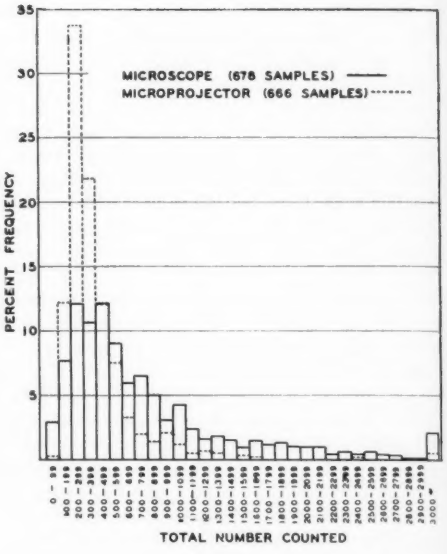

Fig. 7.
Frequency of total number of particles counted using microscope and microprojector.

counting only 10 fields, there is some point, possibly around 1000, where the chance of inaccuracy in counting appears and becomes more severe with increase in concentration. It is advisable to count only 500 to 750 particles total since there is little improvement of reliability with greater numbers of particles.

Recommended Procedure in Dust Counting

THE FOREGOING points, namely the wide variation in total particles counted, the consequent variation in the reliability of the dust count obtained, the strong possibility of error in counting the higher concentrations, and the lack of a plan in accepting or rejecting the cell counts obtained, show the need for adherence to a standard method. No information uncovered in the preparation of this paper cast doubt on the results obtained from following the standard method initially proposed. However, it was found that considerable doubt is raised when any serious departure from it occurs, especially through attempting to count too many particles or too few. The standard method makes no reference to counting particles in very low concentration. The objec-

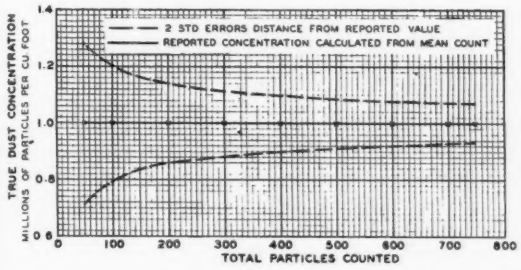

Fig. 8.
Reliability of a dust concentration of one million particles per cubic foot of air when obtained from commonly reported dust counts.

tive of the standard method is to promote uniformity among all workers, so that results will be comparable. New insight into particle distribution shows an easy way to attain the uniformity and reliability of result which was initially intended. Under the standard method, careful adjustment of the concentration will result in a total count of 500 to 750 particles from two cells. Reference to Fig. 1 shows the error of the airborne dust concentration will be between 7% and 9% of the reported value 95 times in 100. The same level of reliability can be obtained by the first dilution if great enough to bring the concentration well under the maximum figure of 75 particles per 0.25 sq. mm. Counting should then continue regardless of the number of fields until at least 250 particles have been counted in one cell, and the last field has been completed. The same number of fields should be counted in the second cell. At least five fields should be counted in each cell for good coverage, and more particles may be counted if desired, but there is little gain in reliability beyond 750 particles. Knowing the total particles counted and the number of fields covered, the mean number per field is calculated. It is recommended, therefore, that dust counting follow the three steps outlined below to attain with greater ease the uniformity and degree of reliability originally intended.

1. Dilute the dust suspension at the outset to a point well below the concentration of 75 particles per 0.25 sq. mm.

2. Count at least 250 particles in at least five fields in the first cell, and the same number of fields in the second cell. Calculate the mean number per field from the total number of fields and the total number of particles.

3. The cells so counted should be accepted or rejected in accordance with the procedure in the section Acceptance or Rejection of Cell Counts.

Summary

THE RELIABILITY of a dust count is easily calculated, and is shown to depend on the total number of particles counted. Statistical methods are used to show that the difference in collection efficiency of two impingers under test is negligible and that samples drawn from a dust suspension for counting are representative. Counting a total of 500 to 750 particles as suggested by the standard method is found to give a possible error of 7% to 9%. It is recommended that 500 to 750 particles be counted in every sample by the method described to attain a uniform level of reliability between laboratories. At this level of reliability, procedures are given for accepting or rejecting cell totals obtained. A third cell is counted in case of doubt, and rules are given for using all three or rejecting one of the original pair. An analysis of counts from 1344 dust samples shows that dust concentrations most frequently are based on a total count of 200 to 500 particles. Roughly 7% to 8% of all cell pairs should be tested for acceptability by counting a third cell.

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Emergency Radiation Exposure Control

—DEVELOPMENT OF CRITERIA

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CONSIDERABLE attention has been devoted over the past several years to problems of exposure to ionizing radiation dosages under emergency conditions in which the normally established peacetime maximum permissible dose concepts are not applicable. Admittedly a major area of concern relates to radiation from "fall out" from super weapons, a matter on which there has been much publicity in the popular press in the last few weeks. In addition to the military and civil defense aspects of this situation, the expansion of application of nuclear energy in industry brings with it an increased possibility of situations in which there may be an emergency requirement for exposure of personnel to above the accepted permissible peacetime maximum dose limits.

Emergency exposure as used in this paper refers to those situations in which the following conditions exist:

(1) The radiation dose received by personnel required to be or present in the particular area of interest is above the maximum permissible dose levels, and conditions outlined in National Bureau of Standards Handbook H-59, "Permissible Dose from External Sources of Ionizing Radiation."

(2) The circumstances are such that the exposure cannot be avoided by any reasonable action of the administrative authority involved. Such conditions might include, among others: personnel rescue operations in a heavily contaminated area; recovery of vital equipment; work on contaminated materiel which cannot be delayed due to pressing military or emergency situations in which the alternative to the use of equipment is disastrous from the viewpoint of national interest; entry to contaminated areas to close off utilities or equipment which if allowed to continue in operation will result in devastating explosion, fire or other disasters; and similar catastrophic conditions.

(3) The military situation requires such an exposure in the accomplishment of vital mission objectives. In this circumstance the hazards of radiation exposure must be evaluated in the light of the other hazards of combat such as exposure to injury by conventional weapons.

The problem of operations in areas subjected to fall out from thermo nuclear weapons has resulted in considerable concern and understandable apprehension on the part of the general public with regard to the result of exposures. From the viewpoint of planners it must be recognized that the necessity for activities involving some of the conditions outlined above may occur even if all the passive protective measures for personnel are taken, such as use of shelters, evacuation to areas predicted to be free of fall out; washdown of contaminated structures; and similar procedures.

This paper represents an effort to evaluate the existing available information on the effects of radiation dosages so as to aid in the development of criteria which may be useful in evaluating exposure effects or in the planning of operations falling within the "emergency" situation as defined above. One problem in this regard is that under emergency conditions the decisions as to actions to be taken must usually be made by administrative authority rather than health physics or medical personnel. Such decisions must be based on a number of factors, one of which may be that survival

of the group depends upon exposure of a group or a portion of it to radiation doses well above the maximum permissible exposure doses of daily routine work. Under such circumstances it is essential that the rather complex considerations involved be reduced to the simplest parameters possible.

While there is disagreement on certain phases of this problem, there is rather general acceptance of the data contained in "The Effects of Atomic Weapons"[1] and Volume II, "Radiological Defense."[2] Studies of Dowdy *et al*[3] are frequently cited in relation to the anticipated effects resulting from receiving various total dosages of radiation. Estimates have been to the effect that, based on analysis of Dowdy and other data, delivering a total dose over a longer period of time will materially reduce the effects.[4,5]

The estimated results to humans exposed to filtered 200 to 1000 KVP x-rays measured in air contained in the previously referenced NEPA report and repeated in NBS Handbook 59 are quoted below:

"ACUTE* EXPOSURE — ESTIMATED RESULTS TO HUMANS EXPOSED TO FILTERED 200-1000 KVP X-RAYS, MEASURED IN AIR. The estimates given below apply to the average normal individual. It should be borne in mind that there is considerable variations in individuals' susceptibility to radiation.

A. *25 r and below*: no detectable clinical effects.

1. From animal experiments it would appear that if man behaves like the mouse and drosophila, there will be, due to radiation, a genetic effect which is much smaller than the spontaneous rate of mutations. In other words, the combined result of the spontaneous and the radiation-induced genetic abnormalities would be slightly increased but much less than double the spontaneous rate alone.
2. Delayed effects** possible but highly improbable.

B. *50 r*: only slight, transient reductions in lymphoctytes and neutrophils. No other clinically detectable effects.

1. Incidence of radiation-induced genetic abnormalities is expected to be approximately the same or smaller than the spontaneously occurring abnormalities.
2. Delayed effects possible but serious effects on the average individual very improbable.

C. *100 r*: at this level, nausea and fatigue may be a problem. Reductions in lymphocytes and neutrophils with delayed recovery. Above 125-150 r, vomiting may become a problem.

1. Incidence of radiation-induced genetic abnormalities, which are quantitatively proportional to the dose, will probably still be comparable to or somewhat greater than those occurring spontaneously.
2. Delayed effects, in summation, would be expected to shorten the life expectancy of man on the average by not more than about 1% from all causes, assuming that limited observations on animals can be extrapolated to man.

D. *200 r*: at this level, fatalities, two to six weeks after exposure, might occur in a small proportion of the irradiated individuals. Nausea, vomiting, and fatigue will probably occur in most persons within 24 hours. Definite depression of practically all blood elements, reduced vitality, in most cases with a convalescent period of three to six months. Temporary sterility in some cases and possibly permanent sterility in rare instances.

1. Incidence of radiation-induced genetic abnormalities will be expected to be at least twice as frequent as the spontaneously occurring abnormalities.
2. Delayed effects—that these would be of major consequence in a small percentage of individuals would seem very probable.

E. *400 r*: it would be expected that virtually everyone would be immediately incapacitated by such an amount of radiation, and many would never recover completely. Some deaths would occur in two to six weeks."

It may be deduced from the above that a single dose of up to 100 roentgens delivered in 24 hours or less would produce little or no effects on the ability of an individual or a group to continue their functions. A single

*Received within twenty-four hours.

**The expression, "delayed effects," as used here, refers to any harmful effects attributable to radiation on the recipient of the radiation and manifested at any time subsequent to the period when acute reactions may occur.

dosage of up to about 200 roentgens would produce nausea and vomiting for about one day in approximately 50% of the personnel so exposed with evacuation required for about 25% at the end of one week. Ultimate recovery of all from radiation sickness might be reasonably expected.[6] Acute dosages above this level are certainly expected to produce considerably more casualties and have a serious effect on individual and group ability to continue to operate in either the immediate or remote time. Estimates have been made[7] of the percentage of the working force affected by various dosages delivered in one day and up to periods of as long as three months. Of considerable significance to the planner involved in operations in which acute nuclear radiation exposures are to be received is the fact that even with doses as high as 300 roentgens individuals will be capable of physical activity for a few days before onset of symptoms, even though there was some nausea and vomiting on the first day after the exposure.

One can conceive of a number of circumstances in which repeated emergency exposures to ionizing radiation may be required over a period of several days, a week, or possibly even for months. Under such conditions it is important to have available comprehensive guides as to the probable results of such exposures. In a situation in which emergency exposures are involved as part of a pre-planned operation, the planner must know among other considerations the manhours required, the total time in which the task must be accomplished, the number of personnel available, and the availability of replacements therefor, and the urgency of the particular task involved. The dose to be accepted can then be determined, provided some such guidelines are available as to the effects of such exposure.

The difficulty of extrapolating the results of animal experimentation in studies on x-ray therapy to this specific problem have long been recognized. Nonetheless a number of such deductions have been made.[8,9] One value accepted for some time has been that a dose of 25 roentgens in a single day could be repeated weekly up to a total of eight weeks (total dose of 200 roentgens). MacLean, Rust, and Budey[9] made a number of estimates of doses to which a group of personnel could be exposed and still retain

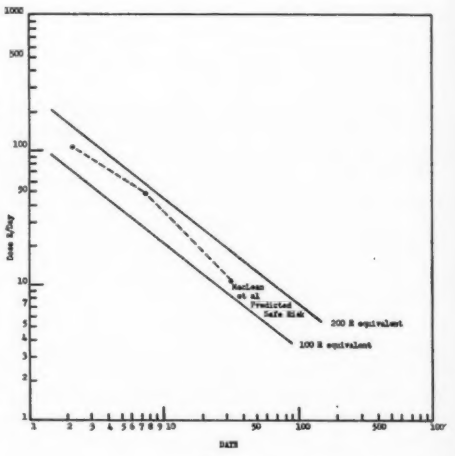

Fig. 1.

their physical effectiveness either for combat or work. In arriving at their conclusions a biological recovery factor of 10% per day was assumed. According to one outstanding authority,[10] no one should be hesitant to accept 25 roentgens in a single dose and under special conditions an emergency dose of 100 roentgens is an acceptable risk. According to this same authority, a total dose up to 300 roentgens might be safely accumulated in a period of 30 days, provided not over 150 r were received in any one day. NBS Handbook 59 states that a 25 roentgen single dose is not presumed to have any effect on the future radiation tolerance status of the individual receiving the dose.

The phenomena of biological recovery while still undergoing exposure to radiation damage must be considered in developing recommendations for emergency exposure. Using the 10% recovery factor cited in the previously referenced work by MacLean *et al*, a 50 r dose per day for five days (250 r total dose) would have the effect at the end of five days of only 205 roentgens. It is recognized that there is a wide diversity of opinion regarding the actual recovery factor. A presentation of biological effect of doses as given in Volume II, Radiological Defense, is shown in Fig. 1. An effective dose resulting from receipt of 50 roentgens per day for five days, utilizing this data is considerably less than that

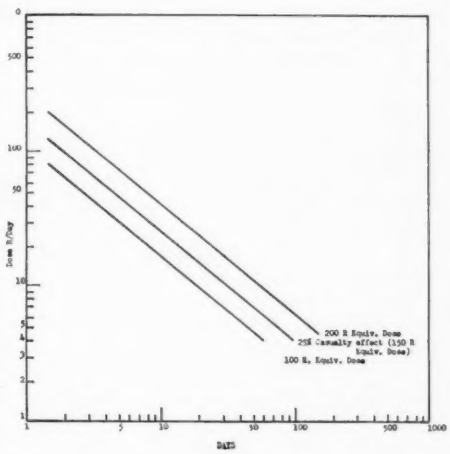

Fig. 2.

estimated in the previously cited work. The doses estimated by MacLean *et al* as being acceptable for maintenance of work or combat unit effectiveness are also plotted in Fig. 1. It is noted this curve lies between the Volume II 100 and 200 r effective dose lines. Of some significance is the fact that the 300 r total dose in the 30-day period suggested by Morgan coincides with the 30-day acceptable risk of 10 r per day, as plotted in this figure.

Another approach to the determination of effects of repeated exposures for varying periods of time is represented in Fig. 2, "25% Casualty Risk Repeated Radiation Doses." Doses estimated to produce sufficient radiation casualties to require evacuation of 25% of the personnel receiving the dose during the period in question are shown compared with the 100 r and 200 r effective dose lines. This determination is based on the data contained in AFM 160-11, Handbook of Atomic Weapons for Medical Officers, and in Radiological Recovery of Fixed Military Installations.

The difficulties inherent in attempting to establish an upper limit on emergency exposures based on either total dose or a biologically effective dose is quite apparent. It may be a relatively simple matter to make an estimate of probable effects of a total dose or of a biologically effective dose. Unfortunately, either the administrative authority or the individuals concerned in the operation in question may, over a period of time in which no actual exposures are involved, accept these values as finite limits between absolute survival and absolute personal disaster. As in the case of threshold limit values for chemical exposures in industrial operations, any values for exposure under emergency conditions must be considered as a benchmark or reference point only and not as finite limits between absolutely safe and certainly dangerous conditions.

Taking the foregoing into consideration an effort has been made, as shown in Fig. 3, "Emergency Radiation Exposure Effects," to develop a rational deduction from available data in terms of expected mission performance rather than in terms of equivalent or total dose. Utilizing the foregoing cited data and several other estimates as to expected effects, a rough approximation results on a purely empirical basis as to zones of effect. Zone A represents a condition slightly worse than the peacetime maximum permissible dose concept and in which the assumed exposures may be tolerated for

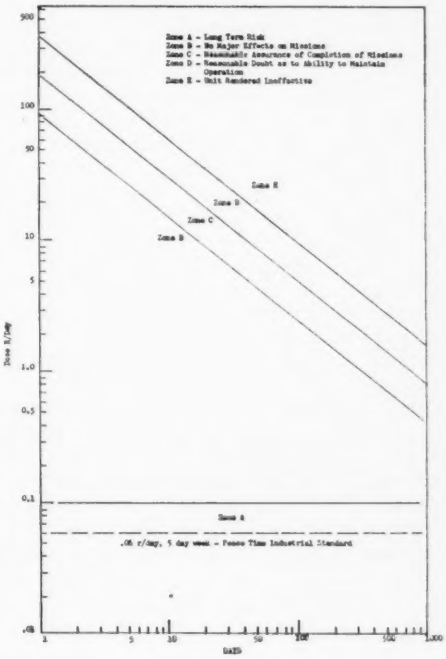
Zone A - Long Term Risk
Zone B - No Major Effects on Missions
Zone C - Reasonable Assurance of Completion of Missions
Zone D - Reasonable Doubt as to Ability to Maintain Operation
Zone E - Unit Rendered Ineffective
Zone E
Zone D
Zone C
Zone B
Zone A
.05 r/day, 5 day week - Peace Time Industrial Standard
Dose R/Day
Days

Fig. 3.

prolonged periods without immediate or delayed effects, provided action can be taken to restrict further radiation exposures at the conclusion of the emergency. Zone B, "No Major Effects on Mission," represents exposure conditions in which the radiation effects on personnel are assumed to be no greater than those incident to normal operations and resulting from other causes. Zone C, "Reasonable Assurance of Completion of Mission," represents conditions in which some immediate and delayed radiation effects will result but not in sufficient numbers or seriousness to preclude completion of the assigned task of the unit. Zone D, "Reasonable Doubt as to Ability to Maintain Operation," represents exposure situations in which immediate and delayed radiation effects can be expected to prevent completion of the assigned organizational task unless replacements are available for those affected. Zone E, "Unit Rendered Ineffective," represents a situation in which exposure effects are such as to disrupt the organizational, administrative, and operational structure to the point of ineffectiveness.

Admittedly this type of estimate leaves much to be desired. In the absence of more finite data it does serve as a useful aid to those concerned with the problem of emergency exposures. It is emphasized that the zones represented in Fig. 3 are a spectrum of conditions, rather than a distinct set of limits. The need for amplified research and study on the problem of emergency exposure is obvious.

It will be noted that nothing has been said about two other facets of the emergency exposure control problem insofar as special weapons operations are concerned, namely the beta contact and the inhalation hazards. Further, nothing has been mentioned with regard to genetic damage. In the first instances, both the beta contact hazard and the inhalation or ingestion hazard are certainly problems to be considered. More than likely, however, under the circumstances defined as "emergency exposures" the gamma hazard is by far the major problem. Secondly, under emergency conditions, as specified herein, the questions of genetic effects appear to be of a second order of magnitude and are beyond the scope of this paper.

In conclusion it should be apparent that there is a twofold implication in the problem of emergency exposures. Since the radiation tolerance of an individual is materially affected by any doses above maximum permissible (discounting the single 25 roentgens dose permitted by NBS 59), every effort must be exerted in normal situations to insure that the radiation tolerance status is not unduly altered and that below acceptable maximum permissible doses are received. Secondly, since emergency exposures will unfavorably alter an individual's future ability to tolerate radiation exposures incidental to occupation, diagnostic or therapeutic x-ray, the utmost care must be exerted to insure that the facts of such emergency exposures as are necessary are carefully recorded and suitable restrictions imposed with regard to future radiation. A major obligation in this regard is imposed upon all concerned with the problem of civil defense and atomic operations.

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The Determination of Fluoride in Urine

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A procedure is described for the quantitative determination of fluoride in urine. The fluoride is separated from a perchloric acid solution of ashed urine by steam distillation of volatile fluorosilicic acid; fluoride in the distillate is titrated with thorium nitrate using alizarin red S as indicator. A statistical evaluation of the precision and accuracy of the method is presented.

THE EXCRETION of fluoride in urine is looked upon as one of two primary defense mechanisms whereby the body rids itself of excessive amounts of this ion. The second major mechanism is that of skeletal deposition. These two bodily reactions to fluoride jointly account for practically all fluoride absorbed by the body.

Urinary excretion of fluoride is prompt. Three hours after the ingestion of small amounts of fluoride by man, approximately one-third of the ingested fluoride will have appeared in the urine.[1] The selectivity of the kidney for fluoride also is outstanding. The fluoride ion does not enter the halogen pool, but instead is selectively excreted to a much greater extent than are chloride and bromide. In the experiment just mentioned, the quantity of fluoride excreted was approximately 70 times greater than would be expected were fluoride excreted as are the other halogens. Moreover, unpublished data obtained in this laboratory indicate that fluoride is cleared from the blood by the kidney at a rate approximately ten times faster than is chloride.

Fluoride concentrations in the urine have been shown to indicate accurately the quantity of fluoride absorbed by the individual in the preceding few hours. Machle has shown that a definite relationship exists between urinary output and the absorption of fluoride in amounts up to as much as 22 mg. per day.[2] Prompt appearance of fluoride in the urine following exposure to airborne fluoride also has been shown by Collings, et al.[3]

Bone changes demonstrable by roentgenographic examination have been correlated with urinary fluoride concentrations. Irwin[4] has stated that no deleterious effects will be seen in man when the urinary excretion does not exceed 5 mg/liter. Largent et al, have suggested that at levels of 10 mg/liter increased density of bones to x-rays may be expected.[5] Hodge and Smith have reviewed the available literature and concluded that in man a level of water-borne fluoride of about 8 ppm can be considered the level for a borderline effect.[1] This would correspond to a urinary excretion of approximately 8 mg/liter.

Inasmuch as the level of urinary excretion corresponding to the production of demonstrable skeletal changes is reasonably well established, it follows that urinary fluoride analyses may be relied upon to detect incipient bone changes and to prevent the development of fluorosis.

Method

THE METHOD to be described is a revision of that reported by Flagg.[6] As in the earlier version, the fluoride is separated by the Willard and Winter distillation,[7] using stills patterned after those in use in the Research Laboratories of the Aluminum Company of America. Fluoride in the distillate is titrated by a modification[8] of the Williams titration.[9]

REAGENTS:

All reagents are Baker's chemically pure

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grade unless otherwise specified. Reagents were prepared with doubly distilled water, obtained by distilling singly distilled water from alkaline potassium permanganate.

1. Acidified thorium nitrate. Dissolve 0.134 g. of Th $(NO_3)_4 \cdot 4H_2O$ in water, add 7.5 ml. of 1.00 N HCl and dilute to one liter. This solution is standardized against the sodium fluoride solution by titrating, as described below, known quantities of fluoride with the thorium solution. One milliliter of the thorium solution is equivalent to approximately 5 μg of fluoride. Blank titrations on doubly distilled water require 0.98 to 1.02 ml. of thorium solution. The magnitude of the blank titration and the equivalence of thorium to fluoride will vary with different lots of reagent and for different analysts.

Fig. 1.
All-glass distillation assembly.

2. Acid indicator (National Aniline and Chemical Company). Dissolve 0.020 g. of monosodium alizarin sulfonate (alizarin red S) in water, add 16.1 ml. of 1.00 N HCl and dilute to 200 ml.

3. Salt solution, 2N sodium chloride.

4. Hydroxylamine hydrochloride (Eastman Kodak Company). Dissolve 2 g. of $NH_2OH \cdot HCl$ in water and dilute to 200 ml.

5. p-nitrophenol indicator (Eastman Kodak Company). Dissolve 0.250 g. of p-nitrophenol in 12.5 ml. of 95% ethyl alcohol and add 37.5 ml. of water.

6. Hydrochloric acid. Solutions of 1.00N and 0.05N are required.

7. Sodium hydroxide. A 1.0N solution is required.

8. Standard sodium fluoride solution. A stock solution is prepared by dissolving 0.221 g. of spectroscopically pure sodium fluoride (Aluminum Company of America, New Kensington, Pennsylvania) in water and diluting to one liter. Dilute 100 ml. of the stock solution to one liter to obtain a solution containing 10 μg of fluoride per ml.

9. Calcium oxide, special fluorine free (Fisher Scientific Company). Each lot should be analyzed for fluoride content; those containing more than 5 ppm are discarded.

10. Anhydrous silver perchlorate, reagent grade (G. Frederic Smith Chemical Company).

11. Perchloric acid, 70-72%.

SPECIAL APPARATUS:

1. Overhead radiant heater for evaporating and charring.[10] By means of a heater of this type urine samples can be safely evaporated and charred in 60 minutes with a minimum of attention.

2. Muffle furnace, Hosking type FD204 with Wheelco Controlling Pyrometer Model No. 224. The capacity of the furnace may be increased to 24 dishes by use of a perforated stainless steel shelf on legs 2¼ in. high.

3. Platinum dishes, 65-75 ml. capacity. These should be cleaned after each determination by boiling in dilute HCl and igniting over a Meker burner.

4. Nessler tubes, tall form, which have been calibrated to contain 70 ml.

5. Comparator block for Nessler tubes, illuminated by a daylight fluorescent lamp.

6. Porcelain spoons, calibrated to measure a fixed weight of dry reagent such as lime or silver perchlorate. Weighing of these reagents is thus eliminated.

7. Stirring rods with flattened tips for powdering ash preparatory to transferring the ash to the still.

8. Fluoride stills and rack. These are illustrated in Figs. 1, 2 and 3. The stills should be of pyrex glass. Blank determinations should be run on each still until a constant blank of 3-4 μg F or less is obtained. A new still may yield high values at first, but upon being boiled out several times with perchloric acid the blank usually is reduced to acceptable levels. If this is not the case the distilling flask and/or head should be discarded. The steam inlet tube and thermometer should give as close a glass-to-glass fit in the wells as practicable. This design of the still head has proved satisfac-

tory in that recoveries of fluoride are good, and the carry over of phosphate and perchloric acid, both of which interfere in the titration, is negligible. The passage of the thermometer and steam inlet tube through the $ 24/40 joint serves as a baffle to minimize bumping over of liquid and silver chloride precipitate. Tubing connections around the steam inlet and thermometer are made with tygon or natural rubber tubing.

9. Florence flasks calibrated to contain 125 ml. to serve as receivers. These should be so selected from stock that the volume of 125 ml. will come up into the neck of the flask.

10. Microburets of 5 ml. capacity, graduated in 0.01 ml.

11. Carborundum chips.

PROCEDURE:

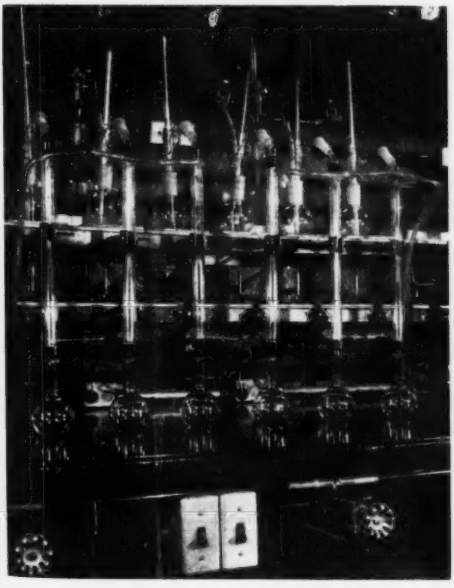

Fig. 2.
Six fluoride stills. This illustration depicts the manner in which a single steam generator serves three stills.

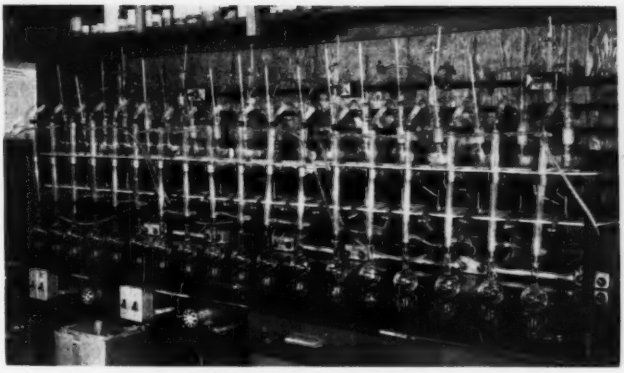

Fig. 3.
A battery of 18 stills.

A. Distillation

1. Twenty-five ml. of urine (graduated cylinder) is placed in a platinum dish containing approximately 1 g. of calcium oxide. A porcelain spoon may be used to measure the lime. After stirring briefly with a glass rod a few drops of phenolphthalein are added to make certain that the sample is alkaline. If it is not, successive portions of lime are added; a note of the total quantity of lime used is kept in order that appropriate reagent blank corrections may be made.

2. The sample is evaporated to dryness under the overhead heater, and charred to a black ash.

3. The dish is transferred to the muffle furnace at room temperature and then ashed at 575°C for six hours; the ash should be grey-white to white.

4. The cooled ash is powdered with a glass rod and transferred through a powder funnel to the distilling flask, which contains 2-3 carborundum chips, several glass beads, and approximately 2 g. of silver perchlorate. This is sufficient silver to precipitate the chloride present in 25 ml. of normal urine. The carborundum supplies silicon to aid conversion of the fluoride to fluorosilicic acid and together with the beads, reduces bumping.

5. The platinum dish is rinsed with a minimal amount of water and perchloric acid, and the washings transferred to the still.

6. The glass joints are wet with water and the still assembled.

7. Ten ml. of perchloric acid is added

through the open steam inlet tube, the latter rinsed down with water, the steam tube connected (with the clamp closed), and the excess water distilled over into the receiver. When the temperature in the still reaches 135°C steam is admitted from the boiling generator flask, and the flame under the still and the steam flow then adjusted to maintain a temperature of 134-37°C. Distillation is continued until 125 ml. of distillate are collected; approximately 1.25 hours are required.

8. The receivers are stoppered with rubber stoppers initially cleaned by boiling in dilute alkali.

9. The stills are cleaned by rinsing thoroughly with hot tap water, followed by distilled water. If kept in constant use no further treatment is necessary.

10. Stills which have not been used recently should be blanked at least once before being used for samples.

The reference to Clifford[11] should be consulted for a detailed description of stills, distillation, interferences and precautions.

B. Titration

1. In a 125 ml. Erlenmeyer flask are placed 0.05 ml. of 1.0 N sodium hydroxide solution and two drops of p-nitrophenol indicator.

2. A 50 ml. aliquot of distillate is added and the solution neutralized against a white background with 0.05 N hydrochloric acid to a faint yellow.

3. From burettes are added (a) 1 ml. of hydroxylamine to reduce any chlorine present from breakdown of the perchloric acid, and (b) 10 ml. of 2 N sodium chloride solution.

4. Add 2 ml. acid indicator solution. The pH of the solution should now be 2.7.

5. Titrate the solution with the thorium reagent, using 0.5 ml. microburette, against a daylight fluorescent illumination. When the faint pink of the thorium lake is first seen, transfer the solution to a Nessler tube, rinse the flask with 5 ml. of doubly distilled water and add the washings to the tube.

6. Continue the titration until the solution matches the color of the permanent standard when viewed under the same conditions in a similar tube. Preparation of the standard endpoint solution is described in Section six of Notes. The matching is done by looking through the depth of the solution.

7. The final volume of titrated solution should be 70 ml ± 1 ml.

CALCULATIONS:

1. The blank titration volume is subtracted from that of the sample and the net volume then multiplied by the fluoride equivalence of the thorium solution. The resulting figure is the number of micrograms of fluoride in the aliquot of distillate titrated.

2. Using the total distillate volume, and aliquot titrated, calculate the total micrograms of fluoride in the distillate.

3. Correct the above value for overall errors using the recovery data described in a later section.

4. Subtract from the recovery-corrected value the previously determined (and recovery-corrected) value for the lime blank.

5. The net value thus obtained represents the total micrograms of fluoride in the 25 ml. of urine analyzed.

Evaluation*

THE TITRATION has a high degree of accuracy. In this laboratory distillate aliquots for titration are chosen to contain 5-80 μg of fluoride; this represents a convenient range for most urines encountered. Data indicating the accuracy of the titration are shown in Table I.

TABLE I.
TITRATION OF KNOWN QUANTITIES OF SODIUM FLUORIDE

Number of samples	26
Concentration range, μgF	5 - 80
Mean recovery, %	99.2
Standard deviation, %	2.4
Range of recovery, %	94.0-104.6

The overall accuracy of the distillation and titration was determined by adding known quantities of fluoride to the stills and carrying out the analysis as described. A summary of the data is presented in Table II.

From the individual data obtained, it was determined that our mean still blank is 2.6 μg fluoride. At fluoride concentrations

*The experiments performed to evaluate the method of determining fluoride in urine were designed and statistically analyzed by Drs. S. Lee Crump and Arthur M. Dutton of the Statistics Section, University of Rochester, Atomic Energy Project. Their contributions are greatly appreciated.

TABLE II.
EFFICIENCY OF THE DISTILLATION AND TITRATION OF KNOWN AMOUNTS OF FLUORIDE

Number of samples	99
Concentration range, μgF	0 - 500
Mean recovery, %	99.3
Standard deviation, %	4.3
Range of recovery, %	86.3-120.0

of 3 μg or less, recovery usually is slightly higher than the actual amount of fluoride present. The percent recovery shows a slight tendency to decrease as the amount of fluoride increases. However, the changes are small.

A series of 23 samples of human urine to which had been added none to 300 μg of fluoride per 25 ml. were analyzed. A careful evaluation of the resulting data indicates that recovery of fluoride is equally good whether fluoride is added directly to the still or is present in 25 ml. of urine which must be ashed with fixative prior to distillation. The data are summarized in Table III.

TABLE III.
RECOVERY OF FLUORIDE ADDED TO HUMAN URINE

Number of samples	23
Fluoride added, μg	0 - 300
Mean recovery, %	100.00
Standard deviation, %	5.9
Range of recovery, %	86.0-114.0

Notes

1. *Fluoride standard.* To date we have been using spectroscopically pure sodium fluoride supplied through the courtesy of the Aluminum Company of America Research Laboratories, New Kensington, Pennsylvania.

Potassium silicofluoride has been suggested as a suitable source of fluoride ion by Clifford,[11] who also describes preparation of the pure salt.

2. *Perchloric acid.* This reagent is purchased in seven pound bottles, from which a small amount is transferred for use to a 500 ml. glass stoppered bottle. The bottles containing the working solution and the stock solution are each kept in ceramic jars of sufficient capacity to contain the entire contents should the bottle be cracked or broken.

3. *Fixative.* Calcium oxide has been the fixative of choice in this laboratory. It has been the practice to purchase one pound of Fisher Scientific Company Special Fluorine Free Calcium Oxide which is then assayed for fluoride content. If the concentration is found to be approximately 5 ppm, an additional several pounds of the same lot number is obtained. One pound of the reagent is adequate for approximately 400-450 analyses.

Calcium hydroxide, prepared by the addition of calcium metal to doubly distilled water, has been used occasionally. Each preparation must be assayed before being used routinely. Different lots of calcium metal apparently contain different, and in some instances appreciable amounts of contaminating fluoride.

4. *Volume of solution titrated.* It is essential that the final volume of the solution being titrated plus the titrating solution be nearly equal to that of the permanent standard. If this requirement is adhered to, it is possible to use one permanent standard of constant volume for all samples. This factor may be readily controlled by proper choice of the aliquot to be titrated. The aliquot may be of any volume equal to or less than 50 ml., and is chosen either on the basis of previous experience or by a preliminary pilot titration. Aliquots of less than 50 ml. are made up to this volume with water.

5. *Interferences.* Interferences in the analysis of urine samples can be expected to be limited to phosphates, sulphates, chlorides, and perchloric acid from the distillation. Effects of these interfering ions on the titration of fluoride are indicated in Table IV.

TABLE IV.
INTERFERENCE OF FOREIGN SALTS IN THE TITRATION OF FLUORIDE (20 MICROGRAMS OF F)

Interfering Ion	Quantity present	μgF Found	Excess Recov'd in Percent
1 ml of 0.1 N HCl	3.5 mg	20.1	0.5
4.6 μg P as PO_4^{---}	14.1 μg	20.2	1.0
11.4 μg P as PO_4^{---}	34.9 μg	23.5	17.5
1 ml of 0.1 N $HClO_4$	9.9 mg	20.0	0.0
0.02 ml of 0.1 N H_2SO_4	0.1 mg	20.3	1.5
0.08 ml of 0.1 N H_2SO_4	0.4 mg	21.2	6.0

The magnitude of the interference in all cases is considerably less than that produced in the back-titration procedure.[11] Phosphates and sulfates are seen to cause

greatest interference. However, the design of the stills is such that the carryover of these ions should be minimal.

6. The use of a permanent color standard against which the unknown is titrated to a color match appreciably increases the speed with which the titration is performed. The working standard is stable for periods of at least six months, thus eliminating the necessity of preparing fresh end point solutions for each three or four titrations. The stock permanent standard consists of 3 ml. of 10% hydrochloric acid, 42.19 ml. of 2% cobaltous chloride, and 30 ml. of 0.1% potassium chromate, made up to a total volume of 100 ml. in doubly distilled water. The working solution consists of 3.2 ml. of the stock solution in 67 ml. of doubly distilled water in a tall-form Nessler tube. Keep the tube tightly stoppered when not in use.

7. *Work load.* One analyst can easily prepare, evaporate and char twelve samples in less than two hours. The subsequent six hours ashing period requires no attention upon the part of the analyst. The distillation and titration of the samples will require the better part of the next day, though during this interval an additional group of 12 samples can be started.

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Course Announced

THE Institute of Industrial Health of the University of Cincinnati announces a course of instruction in *Occupational Skin Problems* to be offered October 10-14, 1955. It will be presented by the Department of Preventive Medicine and Industrial Health, University of Cincinnati, in collaboration with the Occupational Health Program of the United States Public Health Service, and the Department of Dermatology and Syphilology of the University of Cincinnati. The objective of this course is to give physicians a greater understanding of cutaneous problems of occupational origin. The program will be divided into three daily sessions, consisting of morning lectures and clinical demonstrations, afternoon field instruction in industrial plants, and evening panel discussions. The didactic presentations will include a review of the anatomy, physiology and chemistry of the skin. Detailed consideration will be given to the etiology, diagnostic evaluation and treatment of occupational dermatoses, as well as specific measures for prevention and control of these problems. Current concepts regarding cutaneous cancer, allergic reactions and medico-legal problems will be discussed. Applications may be obtained by writing: Secretary, Institute of Industrial Health, Kettering Laboratory, Eden and Bethesda Avenues, Cincinnati 19, Ohio. Early application is advised since attendance will be limited.

The Determination of Acrolein in the Presence of Other Aldehydes

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This paper describes a polarographic method of analysis for acrolein collected on silica gel from a typical workroom atmosphere. Because of its high volatility, acrolein must be transferred to a suitable electrolyte under air-free conditions. After recording the polarogram, the wave height may be compared to standards run in the same electrolyte. The common aldehydes such as, formaldehyde and acetaldehyde, do not interfere. However, crotonaldehyde appears to interfere with the half-wave for acrolein.

IN THE PAINT and varnish industries and also among industries in which petroleum products and vegetable oils are heated, eye irritation is a common complaint. Acrolein, a highly volatile and lachrymatory aldehyde, is one of several products formed in the thermal decomposition of vegetable oils, soaps, and petroleum fuels. Existing methods for the determination of acrolein cannot distinguish it from other less toxic aldehydes such as, formaldehyde and acetaldehyde. The maximum allowable concentrations (M.A.-C.) for formaldehyde and acetaldehyde are five and 200 parts per million (ppm) respectively; that for acrolein is but 0.5 ppm.

To our knowledge it has not been possible to determine acrolein *in air* in the presence of other aldehydes by chemical means. A literature search revealed a polarographic method of assay developed at the Monsanto Chemical Company.* With this as a lead, this laboratory investigated the polarographic method for the determination of acrolein in air. Acrolein shows two reduction-potential waves; the first, due to the reduction of its double bond and the second, due to the reduction of the aldehyde group. It is the reduction-potential wave of acrolein's double bond that makes it possible to distinguish acrolein from other aldehydes, Fig. 1.

With the method of detection established, the next step in the project was the development of techniques for the quantitative collection of acrolein from air. Because of the extreme volatility of acrolein, ordinary bubbler or impinger methods were not possible. Silica gel with its good adsorption qualities seemed to offer possibilities. With

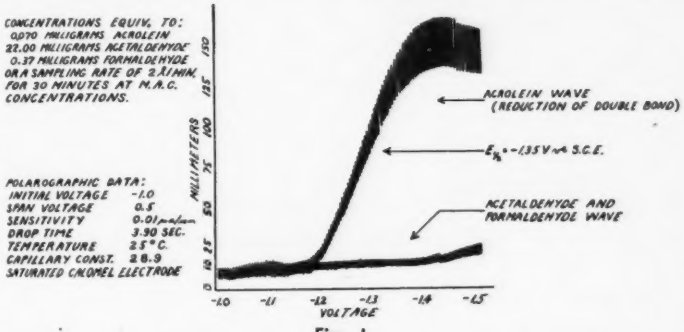

Fig. 1.
Polarogram of acrolein superimposed on polarogram of formaldehyde and acetaldehyde.

Presented in part at the Fifteenth Annual Meeting of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, Chicago, April 28, 1954.

*MOSHIER, R. W.: *Anal. Chem.*, 15:107, 1943.

this in mind, several experiments were performed to determine the effectiveness of silica gel as an adsorbent for acrolein.

Experimental

A WEIGHED amount, 21.0 mg, of acrolein was added to a U-tube, assembled in an adsorption train (Fig. 2) and the pump started. After drawing air for 30 to 45 minutes at two liter per minute, the silica gel tube was removed from the train and weighed. The gain in weight of the silica gel tube was equivalent to the weight of acrolein added to the U-tube. During this experiment Tollen's reagent in a bubbler at the end of the train remained colorless.

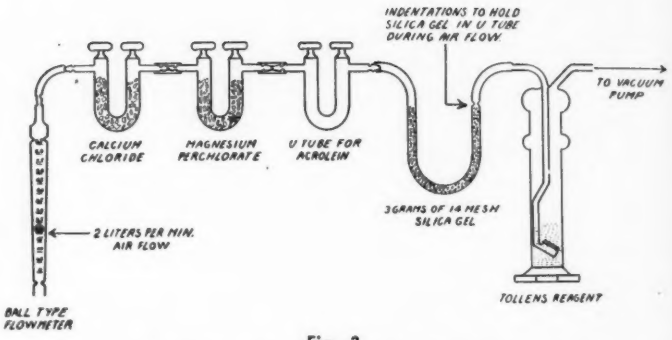
INDENTATIONS TO HOLD SILICA GEL IN U TUBE DURING AIR FLOW
TO VACUUM PUMP
CALCIUM CHLORIDE
MAGNESIUM PERCHLORATE
U TUBE FOR ACROLEIN
3 GRAMS OF 14 MESH SILICA GEL
2 LITERS PER MIN. AIR FLOW
BALL TYPE FLOWMETER
TOLLENS REAGENT

Fig. 2.
Adsorption train for acrolein using silica gel.

The experiment was repeated to study effect of formaldehyde and acetaldehyde. Following the adsorption of acrolein, portions of formaldehyde and acetaldehyde were added to the U-tube. This was pulled through the train for about 30 minutes. Again the Tollen's reagent remained colorless.

Finally the experiment was repeated with a bubbler of water placed in the train to study the effect of high humidity. Again the Tollen's reagent remained colorless, indicating that high humidity will not alter the effectiveness of silica gel as adsorbent.

The next problem that had to be resolved was a means of transferring the acrolein from the silica gel to the electrolyte for subsequent polarographic analysis. As mentioned previously, acrolein is highly volatile and therefore presents complications in transferring to an electrolyte. Further, customary degassing of the electrolyte with nitrogen for polarographic analysis had to be abandoned. Therefore, the supporting electrolyte was first degassed with nitrogen and the transfer of acrolein made under air-free conditions.

Reagents, Equipment and Solutions

THE REAGENTS, equipment and solutions needed to conduct the experiment include the following:

1. Silica gel, 6-16 mesh, Davison Grade A.
2. Potassium phosphate electrolyte. To 200 ml. water add 0.2 gm. KCl and 2 cc H_3PO_4. Add K_2CO_3 until neutral. Then add 14 gm. of KOH pellets. Add H_3PO_4 to bring down to pH 7.4. Add 10 mg. gelatin. Dilute to 500 ml and degas with nitrogen.
3. 7 mm. tubing for U-tubes.
4. Suitable air pump—Willson or Jordan type.
5. Calibrated manometer to collect sample at one to two liters per minute.
6. Sargent Recording Polarograph, Model XXI, or any suitable model.
7. Mechanical stirrer.
8. Torsion balance.
9. Tank of nitrogen.
10. Reagent grade acrolein (Eastman Company) redistilled before preparing standards.
11. Extraction cell.
12. Polarographic cell.

Procedure

AIR SAMPLES were collected by assembling the apparatus as follows: A U-tube made of 7 mm. tubing and packed with 3-4 gm. of silica gel was connected to a manometer calibrated to collect sample at two liters per minute. This was backed up by an air pump of the Willson or Jordan type. After sampling at the rate of two liters per minute for 30 minutes the pump was stopped and the silica gel U-tube removed from the assembly.

The silica gel with adsorbed acrolein was transferred to the specially constructed extraction cell and nitrogen passed through

a few moments to replace the air. Oxygen-free potassium phosphate electrolyte was added in sufficient quantity to cover the silica gel. The cell was immersed in an ice water bath to minimize volatilization of acrolein, since the silica gel warms up considerably on being moistened, Fig. 3.

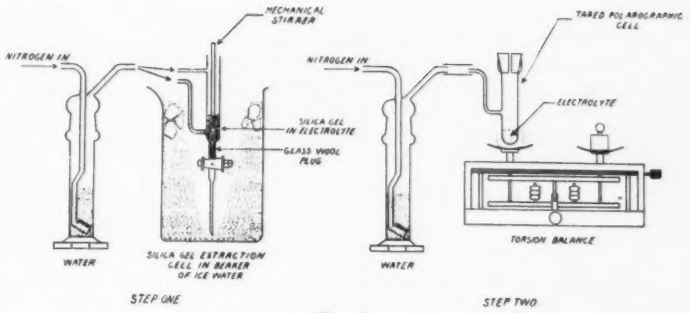

Fig. 3.
Extraction of acrolein from silica gel.

The contents were slowly stirred for 30 minutes under an atmosphere of nitrogen. This portion of electrolyte was transferred to the tared polarographic cell in which the air had been swept out with nitrogen. This extraction with potassium phosphate was repeated twice and each portion combined with the original extract in the polarographic cell. The weight of the electrolyte was recorded and its volume calculated.

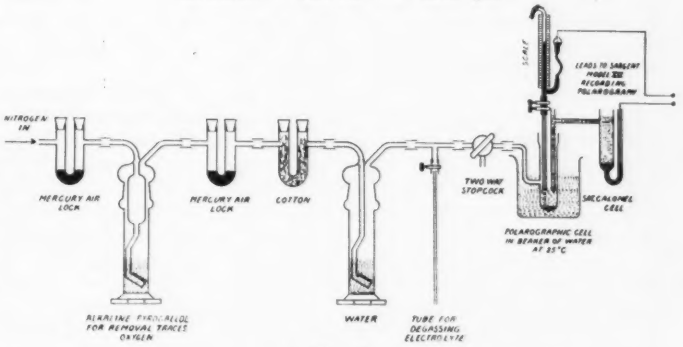

Fig. 4.
Train assembly for polarographic determination of acrolein.

The cell was then connected to a Sargent Polarograph and the wave for acrolein recorded, Fig. 4. The cell was held at 25° C. in a water bath and an atmosphere of nitrogen kept over the electrolyte during the analysis.

Polarographic constants were:

Drop time	4.2 sec. (No applied E.M.F.)
Capillary constant	28.4
Height of mercury column	58.4 cm.
Sensitivity	.03 microamps per mm.
Initial voltage	-.95 v.
Span voltage	.6 v.

After obtaining the recorded wave, the wave height was determined by customary practice of locating the half wave and drawing a vertical line through this point, connecting the two base lines of the recorded wave. This wave height may then be compared to the wave height obtained from prepared standard polarograms.

Acrolein Standards

A STOCK SOLUTION of acrolein was made up by adding a weighed amount of acrolein to a degassed portion of potassium phosphate electrolyte.

The known concentration of stock solution was then diluted with degassed potassium phosphate until a concentration was obtained such that 1 ml. of the electrolyte contained 25-30 micrograms of acrolein. A polarogram was recorded and the wave height in microamperes determined. Several checks revealed the reproducibility of the standards.

Sensitivity

IT WAS FOUND that the polarograph would detect as little as one microgram of acro-

lein per ml. of electrolyte. If an atmosphere containing the M.A.C. (0.5 ppm) of acrolein were sampled at a rate of two liters per minute for 30 minutes, 68.4 micrograms of acrolein would be collected. An alcohol solution of acrolein was prepared and an aliquot containing this amount of acrolein was placed in a U-tube in the train. The acrolein was collected on the silica gel and a polarogram recorded. By calculation it was found that only about 50% of the acrolein added was recovered. In subsequent work this factor of 50% recovery appeared to be consistent so that in actual practice a correction could be applied. The authors suggest that polymerization of the acrolein on the silica gel may account for the low recovery. Further work is planned to investigate this possibility.

Field Sampling

THE RESULTS of some field experiments are tabulated in Table I. Simultaneous samples for total aldehyde and acrolein were collected.

Sample #1 is an example where the total aldehyde concentration was below the M.A.C. for formaldehyde, but a definite eye irritation was experienced. The concentration of acrolein found was equal to the M.A.C. and probably accounted for the eye irritation, Fig. 5.

The samples were transported from the field to the laboratory in a picnic ice cooler, keeping them cool until the analysis was done. More laboratory work must be done before it is known whether the above step is necessary. It is planned to collect more air samples in the laboratory, storing them at different temperatures and for different periods of time. Until more is known about the stability of acrolein on silica gel, it is felt that refrigerating field samples is a good procedure.

TABLE I.

Industry	Operation	Sample	Total Aldehydes (as HCHO) ppm.	Acrolein ppm.
Iron Foundry	Mold pouring	1	3.3	0.5
Paint & Varnish Plant	Varnish cooking	2	1.0	< .01
Paint & Varnish Plant	Varnish cooking	3	2.0	0.4

Summary

A POLAROGRAPHIC analysis of acrolein adsorbed on silica gel has been presented. The method is specific for acrolein, and the common aldehydes do not interfere. What would ordinarily be a fairly simple analysis is complicated by the necessity for using air-free conditions because of the high volatility of acrolein. Possibly a redesigned extraction cell could also serve as a polarographic cell, making the various transfers less cumbersome.

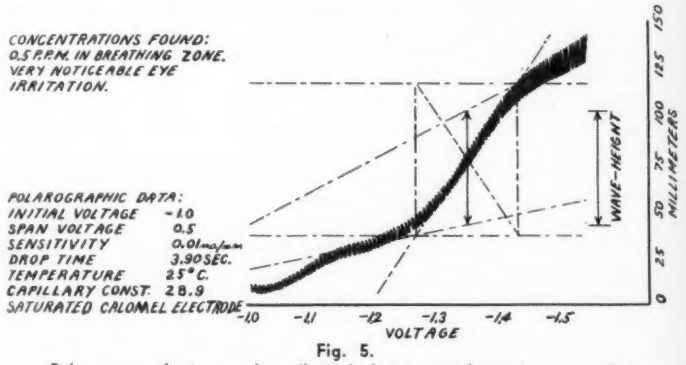

Fig. 5.
Polarogram of air sample collected during metal pouring operation.

THE SECOND Annual Pacific Northwest Industrial Health Conference will be held September 12-13 in Portland, Oregon. The program this year will feature the industrial health program for the small plant.

A COMPARISON OF
Carbon Monoxide Concentrations
IN DETROIT AND LOS ANGELES

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IN THE ATMOSPHERIC pollution problem automobiles have been alleged to be a major contributor. Because of this, the Research Laboratories Division of General Motors has attempted to assess the extent of this contribution. As a part of these investigations tests have been conducted in Los Angeles and Detroit. This paper will deal only with the carbon monoxide tests made in the two cities. These results were obtained both at street level in varied conditions of moving traffic and at 150 feet above main thoroughfares.

That cars could contribute to high levels of carbon monoxide at street level was recognized and reported by Henderson and Haggard in 1923.[1] Tests were made in Philadelphia in 1926[2] and in Chicago in 1928.[3] In this same year Bloomfield and Isbell[4] of the Public Health Service published results of tests made in 14 large cities. The conclusions of these various investigators were essentially the same: the concentration of carbon monoxide in city streets did not constitute a serious public health hazard but long period street level exposures in traffic congestion should not be ignored.

The data to be presented should indicate whether the conclusions of these early investigators are still valid or whether the increased use of automobiles has created a public health problem. In both Detroit and Los Angeles people depend more on private cars than public transportation. The topography and meteorology of the Detroit area are very similar to those of many other large cities. Detroit is flat with average wind motion and limited periods of air stagnation. On the other hand, meteorological conditions, combined with the topography, make Los Angeles highly vulnerable to atmospheric pollution. These conditions should magnify the carbon monoxide exposure and make it equal to or higher than in any other large city, particularly under periods of inversion—or smog. Under such conditions these tests were conducted.

Previously reported street level carbon monoxide results were obtained by stationary sampling. In contrast, street level tests herein reported were made in a car travelling in traffic of varied density. The probe shown in Fig. 1 was used to sample over the right fender approximately two feet in front of the windshield. The port of entry was approximately five feet above street level—to simulate the breathing zone height of pedestrians at the curb. Air passed through the probe to a carbon monoxide indicator located inside the car (Fig. 2). This instrument has been extensively modified. A double scale microammeter has been incorporated with full scale deflection equivalent to 100 parts per million in the low

Fig. 1.

Presented at the 16th Annual Meeting of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, Buffalo, New York, April 27, 1955.

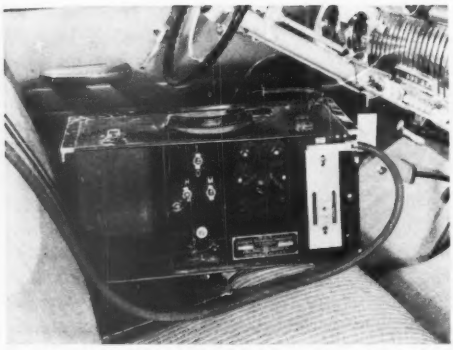

Fig. 2.

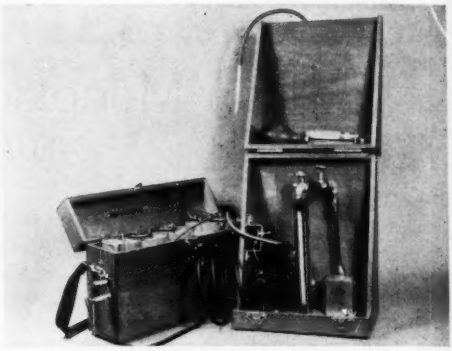

Fig. 3.

range and 1000 ppm in the high range. Zero readings may be established by recirculation of contaminated air through the hopcalite cell within the instrument. This feature allows use of the indicator in areas of high contamination.

The M.S.A. Indicating Tubes shown in Fig. 3 were also used for some of the street determinations and for all tests at the 150 foot level. A sampling rate of 75 ml. per minute was maintained on the rotameter in the circuit. During sampling the time was noted when the color matched the first or second color standard provided with the indicating tubes.

During September, 1952, the first series of tests was made in Detroit. Supplemental tests were made in October, 1953. Three hundred and eighty results obtained in the two series have been combined and plotted in Fig. 4 without regard to traffic density. As can be seen from the curve, 50% of the test results were either at or in excess of 15 ppm carbon monoxide. Only 10% were equivalent to or greater than 40 ppm. The maximum level detected was 80 ppm.

Since concentrations of carbon monoxide are related to the volume of traffic, the Detroit data were replotted in Fig. 5 to show this relationship. The judgment of an observer was the basis for calling the traffic density heavy, medium or light. The same observer was used in all tests.

With heavy, medium and light traffic, the maximum concentrations were 80, 40 and 50 ppm. The mean values were 28.9, 12.3 and 6.9 ppm of carbon monoxide.

The data collected in Los Angeles during

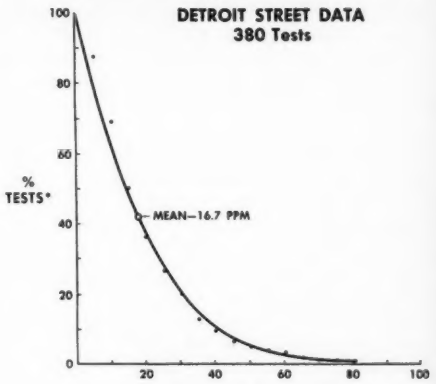

Fig. 4.

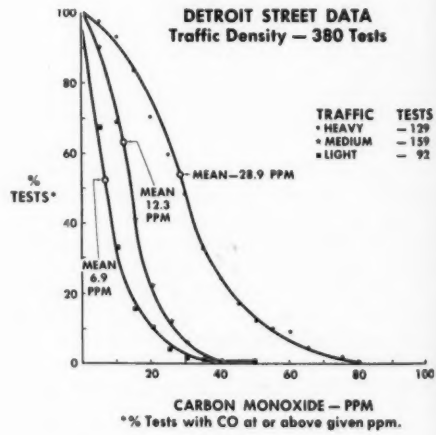

Fig. 5.

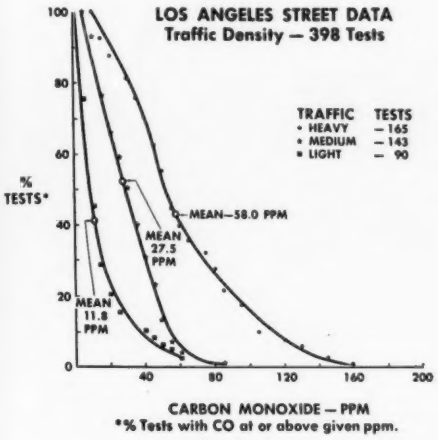

Fig. 6.

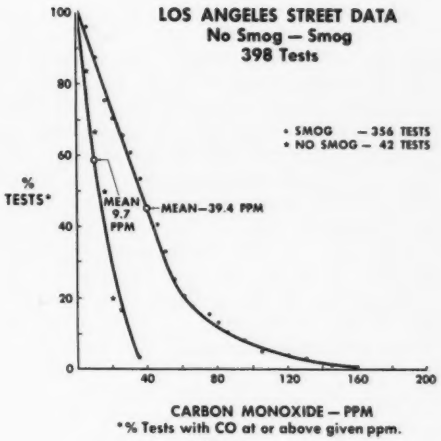
LOS ANGELES STREET DATA
No Smog — Smog
398 Tests
• SMOG — 356 TESTS
• NO SMOG — 42 TESTS
% TESTS*
MEAN 9.7 PPM
MEAN—39.4 PPM
CARBON MONOXIDE — PPM
*% Tests with CO at or above given ppm.

Fig. 7.

September and October, 1954 and November, 1953 have also been combined. The results broken down according to traffic density are shown in Fig. 6. The maximum levels are as follows: 160 ppm for heavy, 85 for medium and 60 for light traffic. The mean levels are 58.0, 27.5 and 11.8 ppm.

A comparison between carbon monoxide levels on non-smog and smog days are of interest. All Los Angeles results were classified in terms of this variable and these data are presented in Fig. 7. The CO levels are higher during periods of smog. The mean values are equivalent to 9.7 and 39.4 ppm. The highest concentration detected, 160 ppm, occurred during smog.

The carbon monoxide concentrations at street level, especially the maximum values detected, are not significantly different from those reported by the early investigators. These findings indicate that the increase in traffic has not increased the hazard to public health from exposure to carbon monoxide.

An increase in traffic certainly suggests higher carbon monoxide levels. Why then do we not find them? J. M. Campbell,[5] Technical Director, Research Laboratories Division, General Motors Corporation has offered a possible explanation. In a paper presented to the Society of Automotive Engineers he pointed out, . . . "In a typical group of cars representing all price classes, carbon monoxide has been reduced to approximately one-half of what it was in 1927. This trend, representing the averages

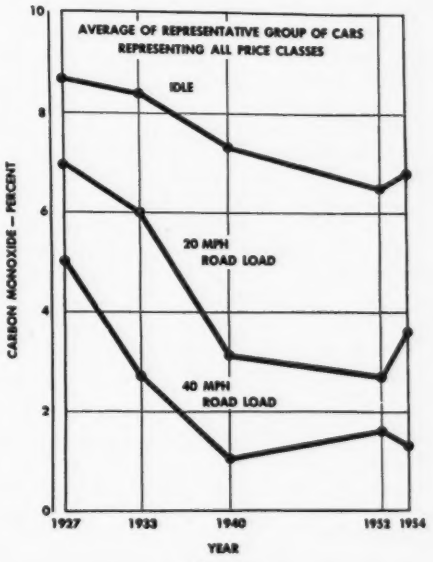
AVERAGE OF REPRESENTATIVE GROUP OF CARS REPRESENTING ALL PRICE CLASSES
IDLE
20 MPH ROAD LOAD
40 MPH ROAD LOAD
CARBON MONOXIDE — PERCENT
YEAR

Fig. 8.
Progress in reduction of carbon monoxide by automobiles, 1927-1954.

of information available in all price classes, is shown in Fig. 8. Further, the trend of the industry has been toward higher compression ratios in the effort to gain in fuel economy. This trend has been particularly significant since World War II when average compression ratios have increased from 6.5:1 in 1946 to 7.7:1 in 1954.

"As a result of these developments, that is to say, use of leaner mixtures and higher compression ratios, coupled with other engineering developments and corresponding improvements in fuels, gasoline consumption has been reduced by approximately one-third with respect to the amount that would have been required in the engines of 1927 to do the same transportation job that we are doing today.

"We believe that this is very significant progress in that it not only means that the industry has brought about a 50% reduction in carbon monoxide content but by reducing the total consumption of gasoline we have reduced by about one-third the amount of total exhaust gas with respect to the amount that would have been produced if this engineering progress had not taken place." Thus engineering advances have offset a three-fold increase in traffic.

As stated earlier, carbon monoxide samples were also collected at approximately 150 feet above the street, the purpose being to determine concentrations of pollutants in a more homogeneous mass of air rather than near a localized source. This was particularly desirable in Los Angeles where photochemical reactions are believed to be an important factor in air pollution. In addition, tests at this elevation should reflect the degree of contamination in the atmosphere immediately above the city. In Los Angeles these levels reflect generalized contamination and tests indicated that similar concentrations existed at ground level in residential areas.

The test station in Los Angeles was on the 11th floor of the Biltmore Hotel above Fifth and Grand. In Detroit the site was the 9th floor of the Research Laboratories Building over Second Avenue near West Grand Blvd.

In Detroit only ten CO determinations were made. The values ranged from an estimated 0.5 ppm to a maximum of 3.0 ppm. The average for this group was approximately 2.0 ppm.

The program in Los Angeles was more extensive. Hourly tests were made on the twelve days preceding "Black Thursday," October 14, 1954. On ten of these days the smog index or oxidant levels by the phenolphthalin method were in excess of the threshold of eye smarting (0.25 ppm).

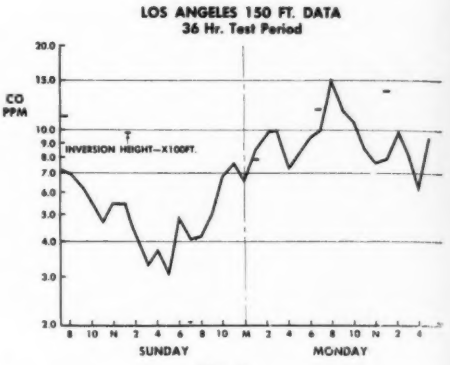

Fig. 9.

The base of the inversion varied from ground level to 4000 feet.

During this period 157 test results ranged between one and 15 parts per million. Only 6% of these tests were above 10 ppm. The average for all tests was 6.0 ppm. The average for tests made only on days when the oxidant level was in excess of 0.25 ppm was slightly higher—6.3 ppm.

Hourly test results for a 36 hour sampling period starting Sunday morning, October 10th and ending Monday evening, October 11th are shown in Fig. 9. The rectangles indicate the height of the inversion layer.

Traffic counts made when tests were in progress showed no correlation with the CO data. This is very evident by the results on Monday at 2:00 and 3:00 A.M. when values of 10 ppm were detected. Undoubtedly the meteorological conditions in the basin were of major importance in the buildup of this pollutant.

It is recognized that higher concentrations than those reported here can develop with a lower inversion. The California Department of Public Health in a recent report[6] on air pollution indicated the highest level detected in Los Angeles to be 43.0 ppm.

Viewed in the light of our present knowledge of the effects of carbon monoxide, the levels found in these tests are not considered high enough to cause concern for the populace at large. Adequate information is not available to judge the effects of these levels of contamination upon infants or those already ill.

Conclusion

TEST DATA on atmospheric carbon monoxide concentrations at street and 150 foot levels support the conclusion that increased usage of automobiles has not increased the hazard due to carbon monoxide.

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4. BLOOMFIELD, J. J., and ISBELL, H. S.: Problem of Automobile Exhaust Gas in Streets and Repair Shops of Large Cities. Public Health Reports, 43:13, 750, (March 30) 1928.

5. CAMPBELL, J. M.: What Are We Doing About Combustion? Presented at S.A.E. West Coast Meeting, Los Angeles, California, (Aug. 16-18) 1954.

6. Clean Air for California. Dept. of Public Health, State of California, March, 1955.

Third Industrial Noise Conference

THE ASSOCIATED Industries of New York State announce the Third Industrial Noise Conference to be held at Kleinhans Music Hall, Buffalo, New York, on Tuesday, November 15, 1955. The meeting will be under the sponsorship of the Association's Technical Committee on Noise in Industry. DR. ALLAN D. BRANDT, Chief Industrial Hygiene Engineer, Bethlehem Steel Company, is Chairman of the Conference Planning Committee. This year's meeting will again highlight industrial noise control, as studies by the Technical Committee disclose that much additional noise suppression data has become available since the subject was considered at the 1953 meeting. Following the precedents of earlier years, concentration will be on the practical rather than the academic. The program will feature descriptions and illustrations by industry people of actual noise control efforts. The subject of ear protectors will receive special attention with particular emphasis being given to actual ear defender programs operated by various companies. Conference plans also call for exhibits by ear defender manufacturers. Further information may be obtained by writing to JOHN M. MCDONALD, Associated Industries of New York State, Inc., 30 Lodge Street, Albany 7, New York.

PITFALLS IN USING Maximum Allowable Concentrations IN AIR POLLUTION

H. H. SCHRENK, Research Director
Industrial Hygiene Foundation, Mellon Institute, Pittsburgh

ECONOMIC LOSSES and various nuisances from air pollution provide a more concrete basis for control of air pollution than claims of adverse effects on health. Nevertheless, when a community initiates a campaign to reduce air pollution, the emphasis is placed on health because this aspect has greater appeal to the public. It is also true that the potential of the effect on health is so great that a meaningful appraisal of such action is highly important.

Admittedly our present knowledge of the health effects of air pollution is inadequate. A major source of basic information is the literature on industrial toxicology, industrial medicine, and industrial hygiene. The contaminants encountered in investigations in those fields are essentially the same as those encountered in general outdoor air. Owing to the demand for acceptable standards for outdoor air pollution, it is natural to turn to the standards which have been developed to prevent injurious and objectionable exposure of workers to inplant contaminants.

There can be no criticism of a desire to utilize the experience gained in inplant studies, but only intelligent application of this knowledge will permit constructive contributions to the air pollution problem. It is necessary, therefore, to have a full understanding of the origin, purpose and limitations of the maximum allowable concentrations established in the field of industrial hygiene, before attempting to use them in air pollution control.

Maximum Allowable Concentration

THE PRACTICE of industrial hygiene is based on the assumption—or we may consider it a fact — that the human body can detoxify, destroy, eliminate, or endure a certain amount of any material without measurable damage or undue discomfort. If we are to apply this principle to prevent harmful or objectionable response, we must define as precisely as possible the stress of the environment and the resistance of man to this stress. If we can define the stress of the environment in quantitative terms of dose based on concentration of offending agent and length of exposure, and define the resistance of man in quantitative terms so that the force of the stress is equalized or overcome by the resistance of the subject, then no adverse response should result.

On this basic concept, comprehensive tables of maximum allowable concentration, permissible concentration, threshold limit or industrial hygiene standard have been promulgated. The validity of these values depends upon our ability to evaluate quantitatively the stress of each individual compound and the resistance thereto, which in turn is dependent upon the adequacy of available information.

Information Used in Establishing Limits

THE INFORMATION used in establishing limit values may be obtained from (a) laboratory studies using experimental animals; (b) laboratory tests using human subjects; (c) field investigations which combine environmental and clinical data; and (d) combinations of these methods.

Laboratory experiments with animals are commonly used and offer certain definite advantages. The environment can be controlled within accurately defined limits for a wide variety of conditions. Thus the stress factor is well defined. Although the resistance factor also can be measured with reasonable accuracy for a number of differ-

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ent species of animals, a weakness lies in the limitation of translation of animal data in terms of human response. But such tests do provide useful information on the nature of injury likely to be produced and may indicate response likely to be of diagnostic value.

Laboratory tests using human subjects obviously must be limited in scope so that there will be little likelihood of injury to the subject. This attentive work requires that previous data be available on the toxicity of the material being studied and in it consideration must be accorded to the definite margin between mild physiological response or sensory effect and possible injury. The procedure provides precise data on both stress and response and may indicate effects of diagnostic significance. A disadvantage is its limited application.

Field investigations in which environmental findings are correlated with clinical and physical examinations of exposed persons have served in establishing limits particularly for pneumoconiosis-producing dust. Data obtained in this manner also serve to check previously established limits. A disadvantage of the method is that the sampling required to evaluate adequately the over-all exposure is in excess of that usually obtained. Another criticism is the limitation of clinical findings which may have been produced by previous exposures and hence cannot be properly evaluated. There is also the difficulty of diagnosis of borderline cases. Thus neither stress nor resistance is measured with a high degree of precision; nevertheless, this procedure continues to provide much valuable information, particularly when carried out periodically over an extended period.

The most accurate limits are those based on both comprehensive laboratory studies and field experience. However, regardless of the amount of information available at the time a limit is established, the value is always subject to readjustment if new experience or data indicate that a change is needed.

Criteria Used in Establishing Limits

IN WEIGHING available information for the purpose of arriving at an acceptable limit of exposure, consideration must be given to: (a) pathological effects; (b) slight physiological effects which apparently have no discernible untoward effects on health, but cause impairment of coordination and reaction time and tend to make workers more prone to accidents; (c) discomfort or sensory effects. In those cases where limits have been established on the basis of pathological effects, it is logical to assume that repeated exposure to concentrations significantly in excess of the allowable concentration probably would produce injury. Where the limit has been established on the basis of a slight physiological effect, it is not logical to assume that exposure to concentrations exceeding the allowable concentration would necessarily produce injurious effects. It is quite possible that the margin between a concentration that would produce mild response and the concentration that would produce injury would be large, in which case exposure to a concentration considerably higher than the allowable concentration might not be injurious to health. The same is true for maximum allowable concentrations that have been established on the basis of sensory effects or discomfort. In this case the margin between sensory effects and actual damage to health may be even greater. It is obvious, therefore, that in using a permissible limit, one must know the criterion used in establishing the limit. In other words, all the limits cannot be interpreted in terms of potential injury to health.

Application of Limit Values

ASSUMING that a limit has been established with a high degree of accuracy, the next step is its practical application. The ultimate goal of limit values is the prevention of harmful or objectionable effects and this goal is accomplished by the use of the limits as a guide in establishing engineering control procedures. Obviously, engineering control does not aim at a precise limit, but at a level of performance which will be consistent with conservation of health. Air analyses are used to check the mechanical effectiveness of the controls, but they also have their limitations in providing an integrated measure of contamination owing to the practical problem of the large number of analyses required. Those specialists who have monitored industrial exposures by periodic analyses recognize the fact that

occasional exposures to high concentrations which occur because of faulty operation or a careless worker can have a significant effect on the response of workers. In the final analysis, the degree and stability of the control will define the magnitude of the stress. An important point to emphasize for this discussion is that man-made controls confine the stress of the offending agent within acceptable levels and thus this factor can be defined with reasonable accuracy. Regardless of the accuracy with which the stress is measured, it does not permit a final conclusion regarding the ultimate response to the stress.

The other factor to be evaluated is the resistance of the exposed workers to the stress imposed on them. Here we are confronted with considerable variations, not only with the range of so-called normal, healthy individuals, but also those who are hypersusceptible and those with pre-existing impairments which decrease their resistance. To bring the resistance factor within reasonable limits requires medical supervision. The pre-placement physical examination serves to eliminate those with defects which obviously would make poor risks to certain occupational stresses. The periodic physical examination serves as a further check on those persons whose resistance is measurably less than the vast majority of similarly exposed persons. Continued medical surveillance provides an additional means of confining the range of the resistance factor within meaningful quantitative limits. Thus, through medical control, workers in industry can be a select group of adults in relatively good health who are continually under medical supervision with special attention to the stress of a specific occupation.

The integration of the engineering and medical controls permits a balancing of the stress factor against the resistance factor to reach the ultimate goal of conservation of health. Both the stress factor and resistance factor are dynamic; that is, they are continually changing and require continuous maintenance to assure that the changes remain within narrow limits. Hence the effective ultilization of acceptable levels of exposure depends on the ability to establish effective environmental and medical controls.

It is evident from a review of the development of maximum allowable or threshold limits that they are actually acceptable levels which serve as a guide in establishing engineering control. They pertain to individual compounds, for periods of eight hours daily for five days per week. The levels constitute neither a method of diagnosing disease nor a proof of the absence of disease. They must have effective engineering and medical control for proper application.

Effect of Air Pollutants on Health

THE EFFECTS of air pollutants on health may be divided into three main categories: (a) acute effects due to a single agent liberated in relatively large quantities in a localized area; (b) acute effects of nonspecific agents encompassing an entire community; and (c) chronic effects on community health. Examples of the first are poisoning by beryllium in Ohio, hydrogen sulfide in Mexico, manganese in a Scandinavian country, mercury in Austria, and chlorine in New York. In each instance a single substance was involved in a limited area. Such occurrences may in general be classified as fortuitous and thus are distinct from the usual air pollution problems. Examples of the second type are the episodes in the Meuse Valley in Belgium, in Donora, Pennsylvania, and in London, England, which have been discussed so frequently that nothing further need be said. One can only speculate on the third category, chronic effects, owing to lack of adequate information and the extreme complexity of the problem.

Environmental Aspects of Air Pollution

AN APPRAISAL of the environmental stress as it relates to health necessitates the study of the offending agents both qualitatively and quantitatively. Although numerous contaminants have been demonstrated in community atmospheres there are undoubtedly many others that have not been identified owing to limitations of analytical procedures. These same limitations pertain also to the quantitative aspects. It is evident, however, that community air pollution constitutes a complex mixture of gaseous and particulate matter which varies greatly in both composition and concentration from

place to place and from time to time. Hence it is immediately obvious that one cannot define the identity of the offending agents of air pollution with the degree of precision that is familiar in industry where individual substances are involved.

The next step is an analysis of the degree of exposure in terms of concentration and length of exposure. A review of available data shows that the concentration of pollutants varies widely. For example, in the Detroit-Windsor investigation during a period of 42 days, the concentration of calcium varied at one station from 0.1 to 14.1 micrograms per cubic meter, a ratio of 141 to 1. While this ratio is exceptional, ratios exceeding 20 to 1 were common and few ratios less than 10 to 1 were noted. A similar relationship was observed for various other elements as lead, iron, copper, and aluminum.

Another example of the variations encountered in air pollution measurements is the result obtained on consecutive two-hour samples collected with an automatic smoke sampler. The amount of material collected was estimated by measurement of light transmission and the findings were recorded in terms of smoke units, increasing numerically with increase in density. For purposes of comparison, readings less than three indicate clear skies with no visual evidence of general air pollution. Values greater than three but less than nine indicate gradually increasing evidence of pollution, and values above nine indicate periods of marked pollution. During the month of July, 1954, a month of very low pollution, approximately 97% of the readings were less than three, and only two values were higher than four, namely, 4.2 and 4.4. However, in November, 1953, only 50% of the values were less than three; 80% were less than five; 10% more than five but less than nine; and 10% were more than nine, the highest value being 12. During that month there were seven periods when values above eight were noted, as follows: Two periods of four hours, one of six hours, two of 12 hours, and two of 18 hours. Also during the month there were 22 periods ranging from four to 58 hours in which the values were less than three. Thus there are wide variations in the concentrations of air pollutants from day to day, from week to week, and from month to month. Since these variations are the result of different weather conditions which cannot be controlled, one cannot define with any degree of exactness the stress exerted by the pollutants. It is also evident that the stress does not exist continuously 24 hours a day but rather consists of a series of episodes of infrequent occurrence and indefinite periods of duration which exceed a level which can be accepted as having no effect on health. Such a baseline seems reasonable as it is impossible to have perfectly clean air.

To further analyze possible health effects one must consider the resistance of the exposed population. In the latter are included everyone from the new born baby to the oldest inhabitant of the community; persons with every type and degree of impaired health; and those who are hypersusceptible or allergic. It is obvious that it is virtually impossible to assess the resistance of such a diverse group. The problem is complicated not only because of the difficulties of differential diagnosis but also by the fact that very little is known regarding the action of a mixture of gaseous and particulate pollutants. Another factor is the recovery periods which occur between periods of high and low pollution. The difficulty of appraising the chronic effects of air pollution on health is demonstrated by the fact that research approaches to the problem have not been marked out with exactness.

Thus, when the stress of air pollution is analyzed, it is found that it consists of a complex mixture of gaseous and particulate matter which is ill-defined. Both composition and concentration vary widely and cannot be controlled. An analysis of the resistance of exposed population shows that this also is a variable which cannot be adequately described. In other words, neither the acting force nor the resistance to it can be set forth in meaningful quantitative terms.

Industrial and Community Exposures

AN ANALYSIS of the stress of industrial exposures reveals that usually a single well-defined agent is involved and that the level of exposure can be confined to rather narrow limits by engineering control. The effectiveness of the controls can be continuously checked by analytical methods, thus assuring proper maintenance. The period

of exposures, in general, is limited to eight hours daily, five days per week. Thus all factors—offending agent, level of exposure, and duration of exposure — are subject to reasonably accurate determination and control.

On the other hand, in community exposures, the offending agent is a complex mixture of gases and particulate matter, usually of poorly defined composition and with wide variations in concentration under the influence of weather conditions which cannot be controlled. Exposure periods to levels which may have adverse effects are likewise indeterminate. Thus none of the factors is subject to adequate determination and, of particular importance, is not subject to control.

An analysis of the resistance of an industrial population to well-defined stress shows that a select group of adults in relatively good health, based on medical examinations, is involved. Furthermore, medical surveillance serves as a check to eliminate susceptible persons and to remove from exposure persons with lowered resistance from some natural disease entity. In industry there is definite medical control that serves to keep the stress and resistance at acceptable levels and to minimize adverse effects.

On the contrary, the resistance of the exposed population of a community ranges from the weakest to the strongest and no practical means of eliminating the highly susceptible is available. This factor becomes even more vague in view of the fact that the stress factor is also indefinite.

MACs Not Applicable to Air Pollution

IT IS CLEAR from a comparison of the essential factors involved in the evaluation and control of industrial exposures with the essential factors related to exposure to community air pollution that these two types are entirely different. The application of acceptable levels of air contamination to industrial areas is based on an integration of engineering and medical procedures to enable a continual check on the effectiveness of control measures which can be adjusted according to needs.

The limitations of the acceptable levels of exposure used in industry and the checks and balances required for their effective use show plainly that those levels cannot be applied to the field of air pollution which consists of unknown and variable factors that cannot be controlled. Acute effects of air pollution on health have been observed at levels much lower than those found to be safe in industry. This fact may encourage attempts to use arbitrarily, fractions of the threshold limits on the basis that resistance is less and exposure longer. However, if the limits themselves are not applicable owing to the marked differences in the basic principles involved, then the same applies to any fraction thereof. Such arbitrary limits would be without foundation and meaningless.

The fact that industrial hygiene limits are not applicable to communal air pollution should not inhibit the use of the toxicological information and experience accumulated in the fields of industrial hygiene and industrial medicine. Intelligent interpretation and utilization of available data can contribute to a better understanding of the air pollution problem and serve as a guide in the development of the research programs which are essential to a sound evaluation of the chronic effects of air pollution on health.

National Safety Congress

THE FORTY-THIRD National Safety Congress will be held in Chicago October 17-21. Sessions are scheduled at the Conrad Hilton, Congress, Morrison and La Salle hotels. Further information may be obtained by writing R. L. FOURNEY, General Secretary, National Safety Council, 425 North Michigan Ave., Chicago 11, Illinois.

AMERICAN

Industrial Hygiene

ASSOCIATION

Hygienic Guide Series

Hygienic Guide Series

THE AMERICAN INDUSTRIAL HYGIENE ASSOCIATION QUARTERLY announces the publication of a series of information bulletins, called Hygienic Guides, which will be made available to industry and other interested persons. This series is a development of AIHA through its Hygienic Guides Committee.

The purpose of the Hygienic Guides is to present authoritative and substantiated information on the toxicity of common industrial materials. It is also the purpose of these Guides to bring together all of the pertinent information required for hazard evaluation. It is planned that Guides will be prepared covering all of the common industrial chemicals and materials. Also, it is hoped that Guides can be prepared for the new chemicals introduced to the industrial markets.

Each Hygienic Guide will include information on the following:

1. Maximum allowable concentration for both short and long term exposures.
2. Significant chemical and physical properties.
3. Major uses.
4. Evaluation of exposures.
5. Engineering control procedures.
6. Medical control procedures.
7. References to the literature.

Present plans are to publish five of these Guides in each issue of the Quarterly. They will also be made available in single sheet reprint form. The Guides in this form can be punched and kept in notebooks for easy reference.

Hygienic Guide sheets may be obtained from the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, 14125 Prevost, Detroit 27, Michigan at 25 cents each. All orders for less than $2.00 must be prepaid.

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HYGIENIC GUIDE SERIES

ACETALDEHYDE

(Ethanal, acetic aldehyde, aldehyde)

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 HOURS): 200 parts of vapor per million parts of air (ppm).[1]

(1) *Basis for Recommendation*: Irritant properties to eyes and respiratory organs of humans.

B. SEVERITY OF HAZARDS:

(1) *Health*: moderate. Effects are primarily irritation of mucous membranes.

(2) *Fire*: severe. Explosive limits are 4.0 to 57.0% by volume. Flash point is -17°F (closed cup). Reacts violently with oxygen.

C. SHORT EXPOSURE TOLERANCE: No data, other than 1100 ppm causes severe mucous membrane irritation in animals.[6]

D. ATMOSPHERIC CONCENTRATION IMMEDIATELY HAZARDOUS TO LIFE: Unknown.

II. Significant Properties

A volatile, colorless liquid with a fruity odor. Paraldehyde and metaldehyde are polymers of acetaldehyde.

Chemical formula:	CH_3CHO
Molecular weight:	44
Specific gravity:	0.783 (18/4°C)
Boiling point:	20.2°C
Relative vapor density:	1.52 (air = 1)
Vapor pressure:	740 mm Hg at 20°C
Solubility:	In water and common organic solvents
Odor threshold:	0.004 mg/l (2.3 ppm)[5]
1 ppm of vapor (25°C. and 760 mm Hg):	0.00180 mg/l
1 mg/l of vapor (25° C. and 760 mm Hg):	556 ppm

III. Industrial Hygiene Practice

A. RECOGNITION: May be recognized by its odor and irritant effects. Major uses are in the plastic, synthetic resin, photography, chemical, synthetic rubber, disinfectant, and mirror manufacturing industries.

B. EVALUATION OF EXPOSURES: Atmospheric determinations of acetaldehyde can be made by collection in aldehyde-free alcohol, vacuum bulb, or water, followed by analysis with Schiff's reagent, sodium bisulfite, or iodine.[2,3] A Davis Model M-6 Vapo-Tester, properly calibrated, may also be used.

C. RECOMMENDED CONTROL PROCEDURES: Enclosure of processes should be practiced. Process ventilation may be required. This is an exceedingly hazardous industrial chemical from the standpoint of fire and explosion. All piping must be in a nitrogen or other inert atmosphere, and grounding of equipment is a necessity.[4]

IV. Specific Procedures

A. FIRST AID: Usual procedure, such as removal from exposure, washing of affected areas, and irrigation of the eyes with water should be practiced.

B. PROPHYLACTIC: Maintain workroom atmospheres below 200 ppm by means of process enclosure and/or ventilation. The evaluation of workroom atmospheres, as well as design of control methods, can best be done by personnel trained in industrial hygiene techniques. Personal respiratory protective devices, approved by the U.S. Bureau of Mines for protection against organic vapors, may be used for temporary exposures or to supplement other control procedures.

C. SPECIAL MEDICAL (including preplacement): None.

V. Literature References

1. American Conference of Governmental Industrial Hygienists: *AMA Arch. of Ind. Health*, 11:521, 1955.
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CADMIUM

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 HOURS): 0.1 milligrams per cubic meter of air.[1]

(1) *Basis for Recommendation*: Animal experimentation and observations of humans.

B. SEVERITY OF HAZARDS:

(1) *Health*: High for fumes. There are no significant warning properties. In a fire caused by the ignition of the dust on the floor of a cadmium recovery chamber, 23 persons were affected.[7] Recent observations on man and animals indicate that the threshold limit for chronic exposure to cadmium oxide dusts, not freshly generated by heat, might be increased.[8,9]

(2) *Fire*: None.

C. SHORT EXPOSURE TOLERANCE: It has been stated that the lethal dose of thermally generated cadmium oxide for man, doing light work, is not over 2900 min. mg/cu.m.,* and possibly not over half that value for arc-produced fume.[2] In an attempt to reconstruct the conditions of a fatal accident in which cadmium-plated metals were heated,[3] it was concluded on the basis of an extrapolation of animal data to man, that the recommended allowable concentration of 0.1 mg/cu.m. of factory air (representing a cumulative dose of 50 min. mg/cu.m. for an eight hour day) gives an adequate margin of safety for industrial workers.

A case of mild human intoxication in a person exposed to an atmospheric concentration of 0.5 - 0.7 mg/cu.m. with a total exposure of three to four hours has been observed.[6] It is not specifically stated whether the limit set by ACGIH is intended to apply to both acute and chronic types of poisoning. The existence of chronic cadmuim poisoning is controversial.

D. ATMOSPHERIC CONCENTRATION IMMEDIATELY HAZARDOUS TO LIFE: Unknown.

*Sometimes referred to as CT values (the product of the *concentration* in milligrams per cubic meter and the *exposure time* in minutes).

II. Significant Properties

Cadmium is a silver-white, blue-tinged, lustrous, malleable and very ductile metal. It volatilizes and burns with a bright flame when heated in air, producing a brownish-yellow (CdO) fume.

Atomic weight:	112.41
Specific gravity:	8.6 at 20°C
Melting point:	321°C
Boiling point:	767°C

Soluble in acids, insoluble in water

III. Industrial Hygiene Practice

A. RECOGNITION: Operations in which cadmium-plated or cadmium-containing metal parts are subjected to heat treatment, welding or soldering and ore-smelting are dangerous, and require that the threshold of 0.1 mg/cu.m. be not exceeded. Accurate knowledge as to the presence or absence of cadmium in the parts to be subjected to processes involving heat is essential. For example, silver solder ordinarily contains about 20% cadmium. Cadmium fumes have no pronounced odor or immediate effect, but their inhalation may induce, after a few hours, a painful, and sometimes fatal, pneumonitis. A simple qualitative test as developed by Coleman and Goldstone[10] can be conveniently used for detecting the presence of cadmium.

B. EVALUATION OF EXPOSURES: Micro amounts of cadmium in air may be determined by the method described by Church[5] or by the spectrographic method of Cholak and Hubbard.[4]

C. RECOMMENDED CONTROL PROCEDURES: Process ventilation, specifically designed for the operation. Personal respiratory

protective equipment approved by the U. S. Bureau of Mines for protection against *metal fumes* (if hazard is cadmium oxide fume), or *dusts* (if grinding) may be used for temporary or supplemental control. Processes should be closed wherever possible.

IV. Specific Procedures

A. FIRST AID: If exposure has been to fumes or dusts, one of the earliest symptoms will probably be that of respiratory distress. Call a physician at once and advise him of the nature of the exposure.

B. PROPHYLACTIC PROCEDURES: Maintain workroom atmospheres below 0.1 mg/cu.m. of Cd. This can be done by using enclosed processes, and/or process ventilation. Evaluation of workroom atmospheres, as well as the design of process ventilation, should be done by personnel trained in industrial hygiene procedures. Good personal sanitation should be practiced by exposed personnel to avoid ingestion of cadmium.

C. SPECIAL MEDICAL PROCEDURES (including preplacement): None, other than symptomatic to relieve respiratory distress.

V. Literature References

1. American Conference of Governmental Industrial Hygienists: *AMA Arch. of Ind. Health*, 11:521, 1955.
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6. FASSETT, DAVID W. (Eastman Kodak Co., Rochester, N. Y.): Personal Communication.
7. PATTY, F. A. (editor): Industrial Hygiene and Toxicology. Interscience Publishers, New York, 1949.
8. PRINCI, F.: *J. Ind. Hyg. and Tox.*, 29:315, 1947.
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CARBON TETRACHLORIDE

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 HOURS): 25 parts of vapor per million parts of air.[2]

(1) *Basis for Recommendation*: Human experience and observation of experimental animals. Recent extensive animal experimentation indicates organic damage with prolonged exposure at concentrations above 25 ppm.[1]

B. SEVERITY OF HAZARDS:

(1) *Health*: High. Volatility is high and odor is frequently not objectionable at harmful concentrations. Individual susceptibility varies. Exposure may result in narcosis, along with severe toxic damage to the liver and kidneys. Serious illness or death may occur. Intake of alcohol increases the hazard. Skin contact may cause dermatitis.

(2) *Fire*: None.

C. SHORT EXPOSURE TOLERANCE: 1,000-2,000 ppm is reported to have caused human fatalities with one-half to one hour exposure.[6]

D. ATMOSPHERIC CONCENTRATION IMMEDIATELY HAZARDOUS TO LIFE: Unknown, but 3,000 ppm is maximum concentration without adverse effects to rats, with 1/10 hour exposure.[1]

II. Significant Properties

Carbon Tetrachloride is a non-flammable, colorless liquid with a sweetish-like odor.

Chemical formula:	CCl_4
Molecular weight:	154
Specific gravity:	1.595 (20°/4°C)
Boiling point:	76.8°C
Relative density:	5.3 (air = 1).
Vapor pressure:	143 mm of Hg at 30°C
1 ppm of vapor (25°C and 760 mm Hg):	0.0063 mg/liter
1 mg/liter (25°C and 760 mm Hg):	159 ppm

III. Industrial Hygiene Practice

A. RECOGNITION: Carbon Tetrachloride is used as a degreasing and cleaning agent, as a fire extinguisher, as a solvent in lacquers and in rubberizing fabrics, and in the chemical processing and manufacturing industries. It is sometimes used as a component of proprietary solvent preparations to reduce their fire hazards. At elevated

temperatures one of the decomposition products of carbon tetrachloride may be phosgene.

B. EVALUATION OF EXPOSURES: The methods proposed for the determination of total chlorine in chlorinated hydrocarbons—microcombustion or adsorption followed by hydrolysis and chlorine determination—are available, but no one of these is specific, and may not be suitable for mixed solvent exposures involving other chlorinated hydrocarbons.[3,4,5,7] The colorimetric method of Rogers and Kay[8] is likewise not specific. The Mass Spectrometer, as well as the Halide Meter (Davis Emergency Equipment Company), may be used.

C. RECOMMENDED CONTROL PROCEDURES: The best prevention of intoxication is substition by a less toxic solvent. Trichlorethylene, perchlorethylene, and 1,1,1, trichlorethane (methyl chloroform) are all less hazardous and can frequently be used. Chlorinated hydrocarbon solvents cannot be used promiscuously, and controls may be required with these subsititutes. If carbon tetrachloride must be used, the operation should be adequately ventilated and isolated from the general working space.

IV. Specific Procedures

A. FIRST AID: Removal from exposure is of first importance. The victim should be put to bed and a physician called at once. Contaminated clothing should be immediately removed and skin cleansed with soap and water. Eye splashes should be treated with copious irrigation with tepid water.

B. PROPHYLACTIC PROCEDURES: Workroom atmospheres should be maintained below 25 ppm by means of process enclosure and/or ventilation. These determinations, as well as the design of specific control measures should be referred to personnel trained in industrial hygiene techniques.

C. SPECIAL MEDICAL PROCEDURES (including preplacement): Employment should be restricted to persons free of a history of liver or kidney disorders, or of alcoholism. Treatment of affected individuals should be directed toward restoring kidney and liver function. Hospitalization, with complete bed rest, is essential. All urine should be collected and measured. Oxygen therapy should be instituted if any anesthesia has occurred. The use of methionine may be beneficial.[9]

V. Literature References

1. ADAMS, E. M., *et al*: *Arch. Ind. Hyg. & Occ. Med.*, 6:50, 1952.
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BUTYL ALCOHOL (N-BUTANOL)

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 HOURS): 100 parts of vapor per million parts of air (ppm).[1]

(1) *Basis for Recommendation*: Development of eye irritation upon prolonged exposure to levels over 100 ppm.[3,4]

B. SEVERITY OF HAZARDS:

(1) *Health*: Low. Volatility is low and odor response good.

(2) *Fire*: Moderate. The limits of inflammability are 1.5% and 11.3% by volume.[2] Because of the low volatility, however, explosive atmospheres are unlikely, except at elevated temperatures. Flash point is 84°F (closed cup).

C. SHORT EXPOSURE TOLERANCE: Occasional eye irritation at 200 ppm with several hours exposure.[3]

D. ATMOSPHERIC CONCENTRATION IMMEDIATELY HAZARDOUS TO LIFE: Unknown.

II. Significant Properties

Butanol is a flammable, colorless liquid, slightly soluble in water, miscible with most organic solvents. It has a pungent odor resembling fusel oil.

Chemical formula:	$C_2H_5CH_2CH_2OH$
Molecular weight:	74
Specific gravity:	0.810 (20°/4°C)
Boiling point:	117.7°C
Relative density:	2.56 (air = 1)
Vapor pressure:	6 mm of Hg at 25°C
Solubility:	In most organic solvents and in water to the extent of 8.9% at 25°C
1 ppm of vapor (25°C and 760 mm Hg):	0.00303 mg/l
1 mg/l (25°C and 760 mm Hg):	330 ppm
Odor threshold:	Ca. 25 ppm

III. Industrial Hygiene Practice

A. RECOGNITION:

(1) By its odor. It is a lacquer solvent, as well as an ingredient of some rubber and plastic cements. It is also used in the plastic fabrication and chemical manufacturing industries.

(2) By its irritant action on the conjunctiva and mucous membranes, and by its minor skin irritant effects.

B. EVALUATION OF EXPOSURES: Because it is frequently used in association with other alcohols, a specific analytical method is difficult to achieve. In the absence of other alcohols an iodometric estimation of the amount of chromate necessary to oxidize it to butyric acid has been used by Tabershaw.[4] A DAVIS M-6 VAPO-TESTER, properly calibrated, has also been used. The vapors may also be determined by either a gas interferometer or a mass spectrometer.

C. RECOMMENDED CONTROL PROCEDURES: Enclosure of the processes using butanol should be practiced. Adequate ventilation of the surfaces of the benches at which the cementing operations are conducted is recommended.

IV. Specific Procedures

A. FIRST AID: Usual procedures, such as removal from exposure, washing of affected skin areas, and irrigation of the eyes with water should be practiced.

B. PROPHYLACTIC PROCEDURES: Maintain workroom atmospheres below 100 ppm by means of process enclosure and/or ventilation. This can best be done by personnel specifically trained in industrial hygiene procedures.

C. SPECIAL MEDICAL PROCEDURES (including preplacement): None.

V. Literature References

1. American Conference of Governmental Industrial Hygienists: *AMA Arch. of Ind. Health*, 11:521, 1955.

2. COWARD, H. F., and JONES, G. W.: U. S. Bureau of Mines, Bulletin 503, 1952.

3. STERNER, J. H., CROUCH, H. C., BROCKMYRE, H. F., and CUSACK, M.: *AIHA Quarterly*, 10:53, 1949.

4. TABERSHAW, I. R., FAHY, J. P., and SKINNER, J. B.: *J. Ind. Hyg. and Tox.*, 26:328, 1944.

AMYL ACETATE

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 HOURS): 200 parts of vapor per million parts of air (ppm).[1]

(1) *Basis for Recommendation*: Human experience plus animal studies.

B. SEVERITY OF HAZARDS:

(1) *Health*: Little hazard from inhalation below 500 parts per million. Above this, vapors are sufficiently irritating to limit possibility of inhaling very high concentrations. No confirmed reports of serious chronic effects. It may dry and defat skin.

(2) *Fire*: Moderate hazard. Flash point is 77°F. Explosive limits are 1.1% to 7% (?) by volume.[2]

C. SHORT EXPOSURE TOLERANCE: Five hundred to one thousand parts per million for 30 to 60 minutes will produce definite irritation of eyes, throat, and trachea.

D. ATMOSPHERIC CONCENTRATION IMMEDIATELY HAZARDOUS TO LIFE: Unknown, but probably several thousand parts per million.

II. Significant Properties

The item of commerce is a mixture of isomers, consisting principally of n-amyl acetate, isoamyl acetate, and secondary

amyl acetate. It is a colorless liquid with a banana-like odor.

Molecular weight:	130.18
Specific gravity:	0.8756 (20°/4°C)
Boiling point:	148.8°C
Relative density:	4.5 (air = 1).
Vapor pressure:	5 mm Hg at 25°C
1 mg/l (25°C and 760 mm Hg):	188 ppm
1 ppm of vapor (25°C and 760 mm Hg):	0.00532 mg/l
Solubility:	In various organic solvents, and slightly soluble in water.

III. Industrial Hygiene Practice

A. RECOGNITION: Chief use is as a constituent in various lacquer formulas. Exposures are usually from spraying operations.

B. EVALUATION OF EXPOSURES: Sense of smell is unreliable and subject to fatigue. Measure by interferometer or adsorption followed by hydrolysis and titration.[3,4,5] The Davis Model 6 Vapotester, properly calibrated, may also be used.

C. RECOMMENDED CONTROL PROCEDURES: Conduct any lacquer spraying in properly designed spray booth. Keep containers closed. Avoid sparks or open flames while using. Occasional short exposure to small amount needs only good general ventilation. Chemical cartridge respirators, approved by the U. S. Bureau of Mines, for protection against organic vapors, are useful for temporary exposures. Wear suitable protective clothing (gloves, goggles).

IV. Specific Procedures

A. FIRST AID: For eye burns, flush with water for 10 to 15 minutes. For splashes on skin flush off promptly with water. Remove any contaminated clothing. If nose and throat irritation are present from inhalation of vapor, remove from exposure for a day or two.

B. PROPHYLACTIC PROCEDURES: Maintain workroom atmospheres below 200 ppm by means of process ventilation and/or enclosure. The evaluation of workroom atmospheres, as well as the design of control methods, can best be done by personnel trained in industrial hygiene techniques.

C. SPECIAL MEDICAL PROCEDURES: None.

V. Literature References

1. American Conference of Governmental Industrial Hygienists: *AMA Arch. of Ind. Health*, 11:521, 1955.

2. COWARD, H F., and JONES, C. W.: U. S. Bureau of Mines, Bulletin 503, 1952.

3. ELKINS, H. B.: The Chemistry of Industrial Toxicology. John Wiley and Sons, New York, N. Y., 1950.

4. JACOBS, M. B.: The Analytical Chemistry of Industrial Hazards, Poisons, and Solvents, Vol. I, 2nd Edition. Interscience Publishers, Inc., New York, N. Y., 1949.

5. PATTY, F. A. (editor): Industrial Hygiene and Toxicology, Vol. II. Interscience Publishers, Inc., New York, N. Y., 1949.

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✦ President's Page

THE POTENTIAL work of technical committees within AIHA, as initially started by Past-President WALWORTH, is one of the most important steps ever taken by the Association. These committees, now increased to seven in number, are active in the following specialty fields: air pollution, analytical chemistry, engineering, noise, hygienic guides, radiation and toxicology.

It has been necessary to spend some time in defining the scope of the various projects and in determining objectives. A lot of work is being done by many people in each of the specialty areas for which AIHA has committees. Relations with other organizations, duplication of effort, ultimate cost of project and possible return illustrate some of the factors which have been considered.

Over-all efforts are being directed toward several areas. One is expansion of AIHA activities in those fields of direct concern to the Association. AIHA membership is drawn from several disciplines, therefore, technical interests are broad. If the Association does not provide activities in all these fields, then it fails in its responsibility to some of its members and the interest and support of those members will be lost.

AIHA must assume leadership in these fields. For a number of years, AIHA members have been furnishing technical information and know-how to other organizations and groups with no particular credit or recognition coming to the Association. AIHA members have been leaders in many related but outside activities, sponsored by others. There is no reason why our members cannot continue to assume this leadership. It is urged that they do so. However, it is now possible for this leadership to be fruitful within AIHA.

Publication of technical information will be most important. This will serve many purposes including dissemination of valuable information and providing some revenue. Technical information, when developed, will accomplish little unless it is in the hands of those who need and use it. Publication of the work of the technical committees will be a milestone in the affairs of the Association.

Obviously only a small portion of the total membership can serve on these committees. This, however, does not relieve the entire membership of responsibilities for the work these committees are doing. Undoubtedly many members have data and information that would be helpful to the committee work. Why not spend a little time in reviewing material you have. If you have data that might be useful, write to the Coordinator of Technical Committees and tell him about it.

—N. V. HENDRICKS
AIHA President

Instrumentation

A SURVEY of the commercially available instruments for the study of air pollution has been completed by the Subcommittee on Current Projects and Trends of the Committee on Air Pollution Controls of the American Society of Mechanical Engineers. The 46-page report lists all types of equipment with the names and addresses of the manufacturers. A limited number of the reports are available from the Executive Secretary, ASME, 29 West 39th Street, New York 18, N. Y.

✦ Selected Titles and Abstracts

—FROM FOREIGN EXCHANGE JOURNALS

THE FOLLOWING is a partial list of articles, by titles and authors, from journals received by the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION since the June, 1955, issue of the QUARTERLY in exchange for copies of the QUARTERLY.

Additional information on any of the journals or articles may be obtained from: CARROL S. WEIL, Senior Industrial Fellow, Mellon Institute of Industrial Research, 4400 Fifth Avenue, Pittsburgh 13.

I. THE JOURNAL OF SCIENCE OF LABOUR (JAPAN). Vol. 31, No. 2 (1955).

On the Changes of Muscle Chronaxie of Rabbits Poisoned by Carbon Disulfide, Benzene, Mercury and Lead. Masanari Mizuno, pp. 59 to 73.

A Study on Occupational Mercury Poisoning. II. Fujio Oikawa, pp. 82 to 87.

Study on Eosinophilia and Lead Poisoning. Sy. Matsuoka, S. Nishikawa, I. Wakisaka, S. Nakamura, and H. Furuya, pp. 96 to 99.

II. THE JOURNAL OF SCIENCE OF LABOUR (JAPAN). Vol. 31, No. 3 (1955).

On the Changes of Musculus Extensor Digitorum Communis Chronaxie Due to Lead Absorption and Muscle Fatigue. Kenzaburo Tuchiya and Masanari Mizuno, pp. 113 to 120.

Distribution of Arsenic in Blood, Urine and Faeces in Acute Arsenic Poisoning. Masatoma Tachi, Mitsukazu Niinuma, Shizuko Imaizumi, pp. 126 to 132.

A Study of Occupational Mercury Poisoning. III. Fujio Oikawa, pp. 133 to 140.

A Non-Fatal Case of Asphyxia by Nitrogen-Gas. Nobuhisa Nishigori, pp. 156 to 160.

III. THE JOURNAL OF SCIENCE OF LABOUR (JAPAN). Vol. 31, No. 5 (1955).

A Study on Total Protein, Protein Fractions and Alkaline Phosphatase in Serum of Lead Workers. K. Tsuciya, M. Motouchi, T. Sakaguchi, Y. Masuda, and M. Mizuno, pp. 285 to 290.

A Study of Tolerance of Animals to Lead Poisoning. Takahide Kuwaki and Kenzaburo Tsuchiya, pp. 291 to 297.

Effects of Glucuronic Acid and Ascorbic Acid Administration on Work in the Hot Environment. Sy. Matuoka, S. Nishikawa, I. Wakisaka, K. Kano, M. Yoskimasu, and J. Nishida, pp. 298 to 303.

On the Occupational Hazards in Working with Vibrating Tools. Toyohiko Miura, Hirosi Mukai, Tei Taguchi, and Mituro Morioka, pp. 310 to 315.

On the Change of Muscle Chronaxie and Blood Sugar Value of Rabbits That Inhaled Carbon Disulfide and Ether. Masanari Mizuno and Yoshinori Masuda, pp. 316 to 323.

On the 'Filter Paper Dust Sampler'. II. Toyohiko Miura, Kikuki Kimura, Yahatiro Matusita, Norio Isida and Akihisa Handa, pp. 336 to 343.

IV. ARHIV ZA HIGIJENU RADA (JUGOSLAVIA). Vol. 5, No. 3 and 4 (1954).

On Measurements in Investigating Protection Against Roentgen and Gamma Rays. Josip Loncat, pp. 330 to 350.

The Influence of Lead Ions on the Release of Acetylcholine. Krista Kostial, V. B. Vouk and Ljerka Purec, pp. 351 to 354.

Zinc Phosphide Poisoning. I. Simonovic, pp. 355 to 359.

Book Review

DUST IS DANGEROUS: C. N. DAVIES, D.Sc. Published by Faher & Faher Ltd., 24 Russel Square, London. U. S. Distributor: John de Graff, Inc., 64 W. 23rd St., New York 10.

This book first discusses the various effects of dust on the workers. This part is well done. It is followed by a chapter on dust sampling which details the use of the Thermal Precipitator and Eascade Impactor which tend to be used generally in England. Little or no reference is made to the Standard Greenberg Smith Impinger. The following chapter on preventive measures does not go into any engineering figures regarding exhaust ventiliation systems, but treats the entire control methods generally. Radioactive, house and non-industrial dusts are discussed with reference to dermatitis and carcinogenic possibilities. Again specific data is not plentiful, but theoretical possibilities are discussed.

The last, and best chapter, deals with dust explosions. The theory of ignition and other factors of importance are covered. Primarily, this chapter adds to our knowledge. It is apparent throughout the book that coal dust, both from a health and explosive standpoint, are well understood by the writer. To those whose primary interest is coal dust in mining and related operations, the book might be valuable.

—J. R.

✦ Obituary

HENRY TAYLOR HERNDON, Industrial Hygiene Engineer for the Texas Employers Insurance Association and the Employers Casualty Company, died following a heart attack at his home in Arlington, June 20, 1955.

MR. HERNDON was born September 23, 1904, at Saint Jo, Montague County, Texas, at the home of his grandfather, Dr. Henry T. Herndon, a practicing physician. He attended the Greenville, Texas, public schools, the Texas School of Mines, El Paso, Texas, Texas A. & M. College, and Texas Christian University. Before entering the insurance field, he was associated with the Southwestern Laboratories, Dallas, and the Texas Electric Service Company, Fort Worth, as Chemical Engineer and Analytical Chemist. He became associated with the Texas Employers Insurance Association and Employers Casualty Company in 1941 as a Safety Engineer in the field.

In 1947, MR. HERNDON set up the first industrial hygiene laboratory of an insurance company in the southwest. In 1951, he was elected a Fellow of the American Association for the Advancement of Science by the council of that Association. He was considered an authority on air pollution in the southwest, and helped to form the North Texas Chapter of the American Industrial Hygiene Association. He was its first chairman and later served on its board of directors. He also served as chairman of the American Society of Safety Engineers and was a member of the American Chemical Society and the Texas Society of Professional Engineers. He was also member of the vestry of St. Alban's Episcopal Church in Arlington, Texas.

✦ In the News

GEORGE L. WILSON has been appointed Industrial Hygienist in the Department of Industrial Hygiene & Toxicology of The B. F. Goodrich Company, Akron, Ohio.

MR. WILSON, was graduated from Purdue University, and was previously employed by the West Virginia Department of Health, most recently having been Associate Director of the Bureau of Industrial Hygiene there.

New Executive Secretary

THE AMERICAN INDUSTRIAL HYGIENE ASSOCIATION announces the appointment of a new Executive Secretary and a change in the business address of the Association. All communications should be directed to: AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, GEORGE D. CLAYTON, Executive Secretary, 14125 Prevost, Detroit 27, Michigan.

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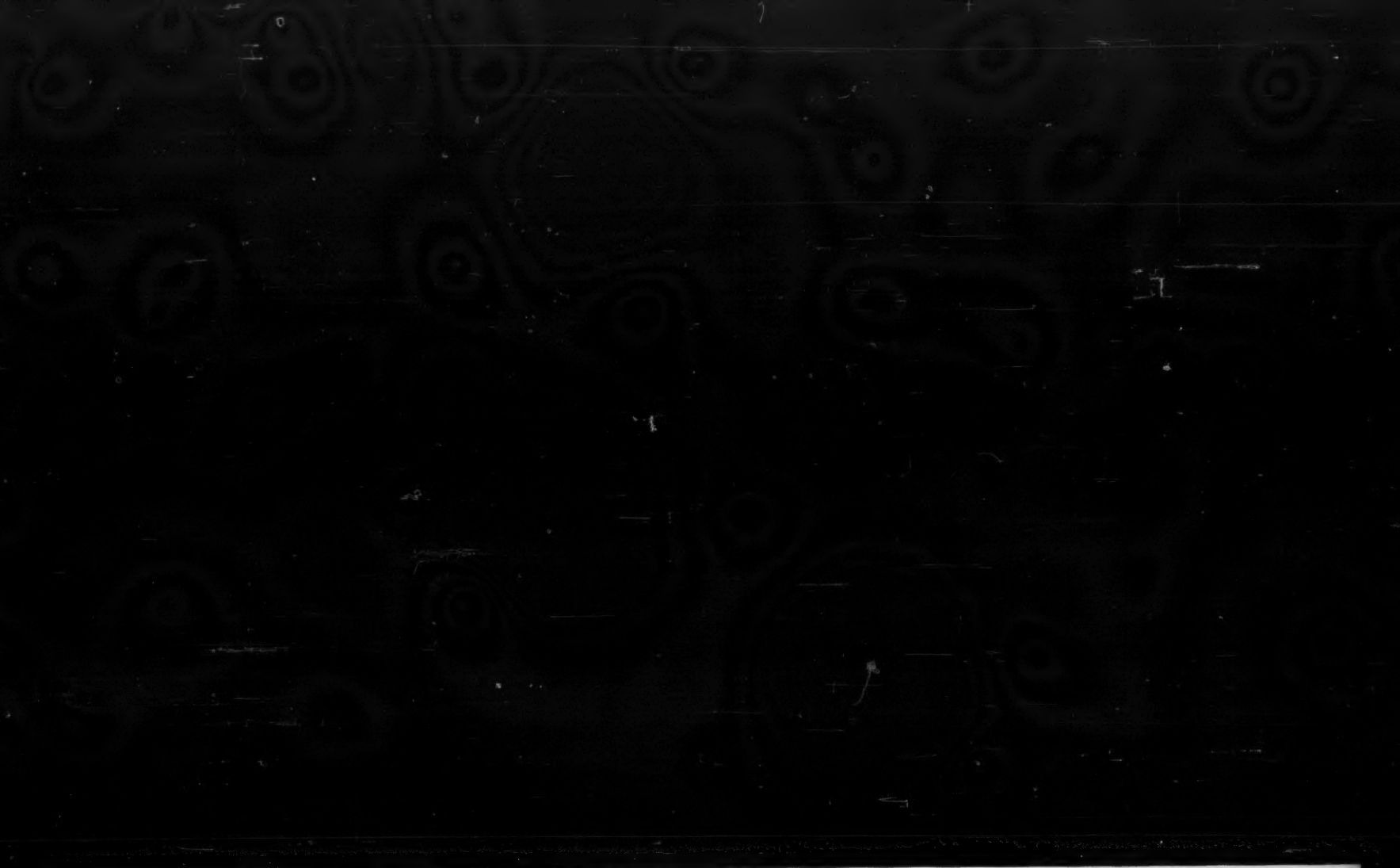
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